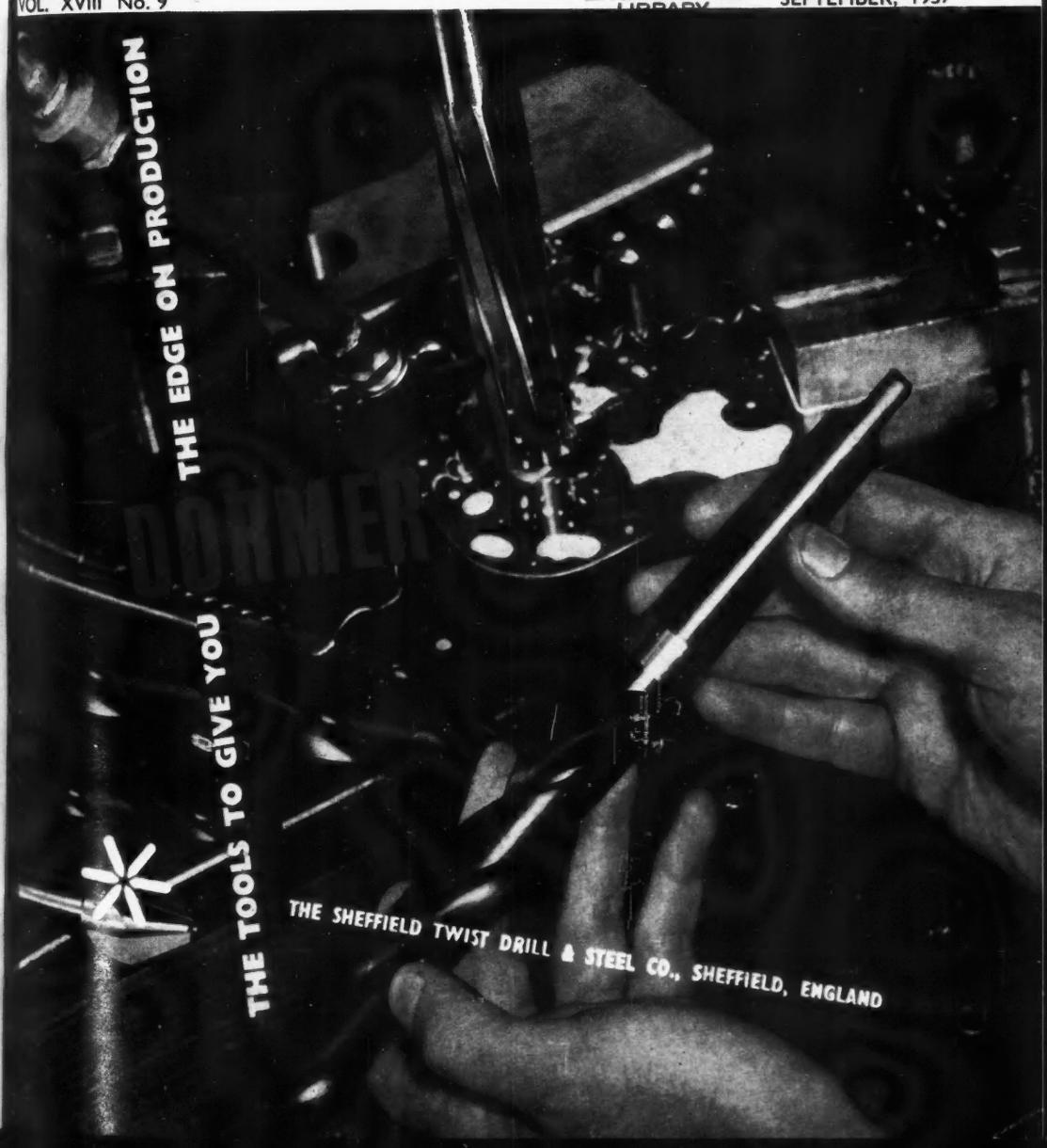
The
ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XVIII No. 9 SEPTEMBER, 1957

ENGINEERING LIBRARY

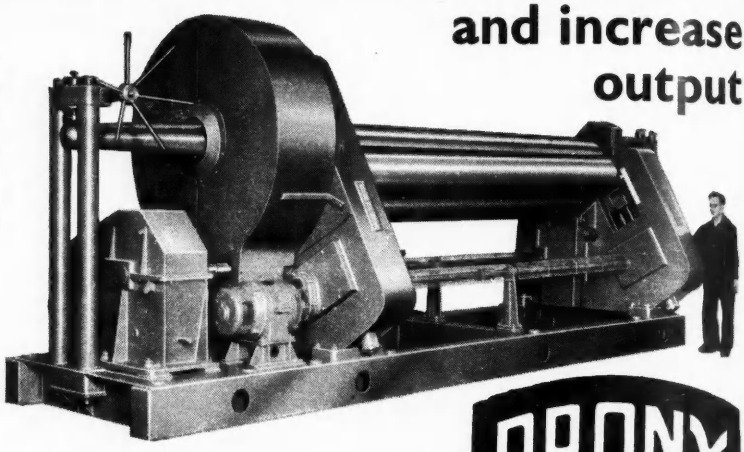


REDUCE *Plate Rolling* COSTS and increase output

Engineering, Marine, Welding, & Nuclear Energy Exhibition

STAND No. 6A GRAND HALL

Olympia, Aug. 29-Sept. 12.



★ *Illustration shows 3-roll machine-capacity 12'0" × ½" Mild Steel Plate. There are also BRONX Press Brakes, Guillotines, Plate & Sheet Levellers, etc.*

For most types of Cylinders or Shells, using this machine, preliminary pre-bending by means of a separate machine is completely unnecessary. Great care and attention has been paid to provide the easiest system of control for the operation. In addition to circling, these machines are also suitable for all types of conical work. There is a wide range of massively built Bronx Plate Bending Rolls to give consistent accuracy with thinnest to thickest steel plates up to 25 ft. wide. ILLUSTRATED LITERATURE ON REQUEST.

BRONX

PLATE BENDING ROLLS

BRONX ENGINEERING CO. LTD., LYE, WORCS. *Telephone: LYE 2307 and 350*

London & S. of England Agents for Press Brakes: W. E. Norton (Machine Tools) Ltd., Grosvenor Gardens House, Grosvenor Gardens, London, S.W.1. *Tate Gallery* 0633/4.

---

now

WRITE FOR A NEW BOOKLET

"Cronite"

REG. TRADE MARK

The HIGH TEMPERATURE ALLOY

SALT, LEAD AND CYANIDE VESSELS
CARBURIZING BOXES AND POTS
ROTARY RETORTS & PROPELLING WORMS
FURNACE HEARTHS AND FITTINGS
ENAMELLING PERRITS AND SUPPORTS
GLASS-BLOWING NOZZLES
PYROMETER PROTECTION SHEATHS
CASTINGS FOR USE AT 700 1200 C.

The **CRONITE FOUNDRY Co. LTD.**

LAWRENCE RD · TOTTENHAM · LONDON. N15

PHONE · STAMFORD HILL 4237

CONTENTS

	Page
The Blue Pages	377
An Appraisal of Ceramic Cutting Tools	381
The Erosive Effects of Pulsed Electrical Discharges with Weak Currents	387
New Oxide-Layer Resistors with Negative Temperature Coefficients	388
Designing Machine Tools for Automatic Control	391
Microsectioning as a Metallographic Technique for Semiconductor Devices	395
Water-Soluble Cellulose Ethers as Binders for Foundry Sands	399
Improved Method of Pressing with Rubber Dies	402
5th European Machine Tool Exhibition	403
British Industrial Developments	413
Additional Abstracts	416
New Materials, Processes, and Equipment	419
News of the Month	421

The ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XVIII NO. 9 SEPTEMBER, 1957

EDITORIAL AND ADVERTISING OFFICES :

GREAT BRITAIN
120 Wigmore Street, London, W.1
Telephone : WELbeck 9357 & 6263

U.S.A.
366 Madison Avenue, New York 17, N.Y.
Telephone : MUrray Hill 2-8865

FRANCE
102 Rue Amelot, Paris (XI^e)
Telephone : VOL. 29-19

ITALY
Via Gran Sasso N.28, Milan
Telephone : 208.741

Annual Subscription Rates :

£2 2s. 0d. in the Sterling area, $7.50 in the Dollar area

Printed in Gt. Britain by THE ALCUIN PRESS, Welwyn Garden City, Hertfordshire, and published monthly by the proprietors, ENGINEERS' DIGEST LTD., 120 Wigmore Street, London, W.1.

PITMAN BOOKS

CATHODE-RAY OSCILLOGRAPHS
By J. H. Reyner, B.Sc., A.C.G.I., etc. 5th Edition. A simple and up-to-date guide to the practical application of cathode-ray tubes to the examination of oscillations or wave-forms and to numerous other purposes. 20/- net.

NUMERICAL METHODS
By R. A. Buckingham, Ph.D.(Camb.). This is a handbook intended primarily for those engaged in hand computation, particularly in the various fields of scientific research. 70/- net.

FOUNDRY PRACTICE
By W. H. Salmon and E. N. Simons. A comprehensive treatment of foundry work which provides not only a practical guide for operatives but also an authoritative textbook on the subject. 32/6 net.

APPLIED THERMODYNAMICS
By W. Robinson, M.E. Revised by J. M. Dickson, B.Sc., etc. 3rd Edition. Covers the syllabuses of the B.Sc.(Eng.), Inst.C.E., and I.Mech.E. examinations in this subject. Pitman's Engineering Degree Series. 40/- net.

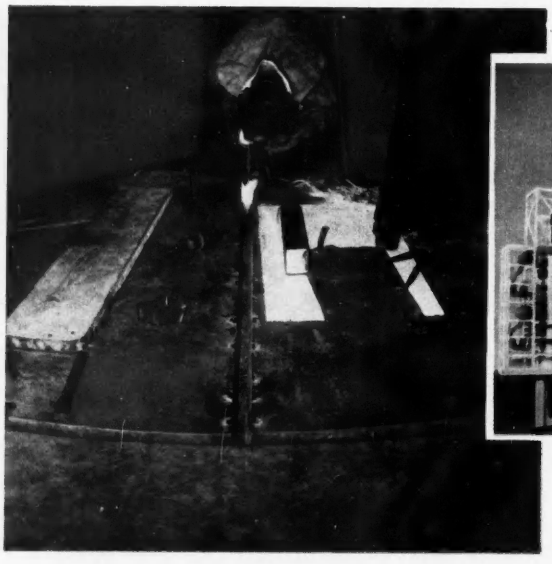
THE GEOMETRY OF SHEET METAL WORK
By A. Dickson. Shows how to apply a knowledge of geometry to the practical problems of pattern development. An important feature of the book is the classification of method as applied to the development of Surfaces. 15/- net.

THEORY OF STRUCTURES
By H. W. Coultas, M.Sc., etc. 4th Edition. This comprehensive book has long been recognised as a standard work on the fundamental principles of the theory of structures. Pitman's Engineering Degree Series. 25/- net.

SIR ISAAC PITMAN & SONS LTD. | **Parker St., Kingsway, London, WC2**

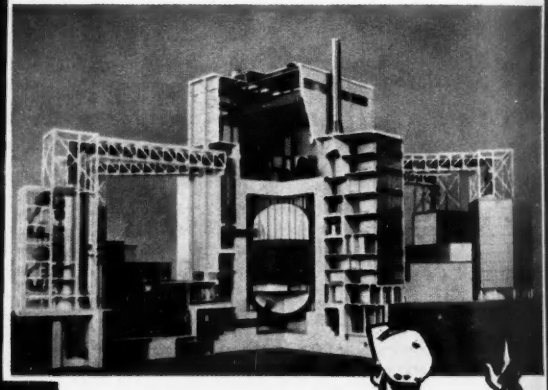
Welding begins inside the bowl of the reactor vessel. Six teams of John Thompson welders work outwards from the centre, welding the 3in. thick steel plates which have been assembled and are temporarily held in position by clamps. Further welding teams began working on the next ring of plates shortly after this photograph was taken. In the background, an X-ray unit stands ready inside the bowl for weld examination.

A welder works from the bottom centre of the reactor vessel, welding together the 3in. thick 'petal' plates which form the lower bowl. Accurate edge preparation of the plates has been achieved by a specially developed flame planing technique in John Thompson's works. The temperature of the weld area is maintained between welding runs by means of flame torches, one of which is seen ready to hand, in front of the welder.



Buttercups at Berkeley...

John Thompson's construction men — familiar in their yellow helmets on power station and industrial sites throughout Britain — are now at work on the Central Electricity Authority's first commercial nuclear power station being built by the A.E.I. — John Thompson Nuclear Energy Company at Berkeley, Gloucestershire. Crisply, the construction programme proceeds to a minutely planned schedule. The bottom dome portion of one of the huge 1,000 ton reactor vessels was transported in sections to the site where it is being welded together to grow simultaneously with the reactor building. The "Buttercups" are speedily getting on with this job in which they are building the reactor vessels, the thermal shielding, the sixteen large heat exchange towers, gas ducting and nuclear fuel loading machines.



JOHN THOMPSON GROUP

JOHN THOMPSON LIMITED

JOHN THOMPSON LIMITED · WOLVERHAMPTON · ENGLAND

THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

• *TESTING OF MAGNETIC-AMPLIFIER CORES*

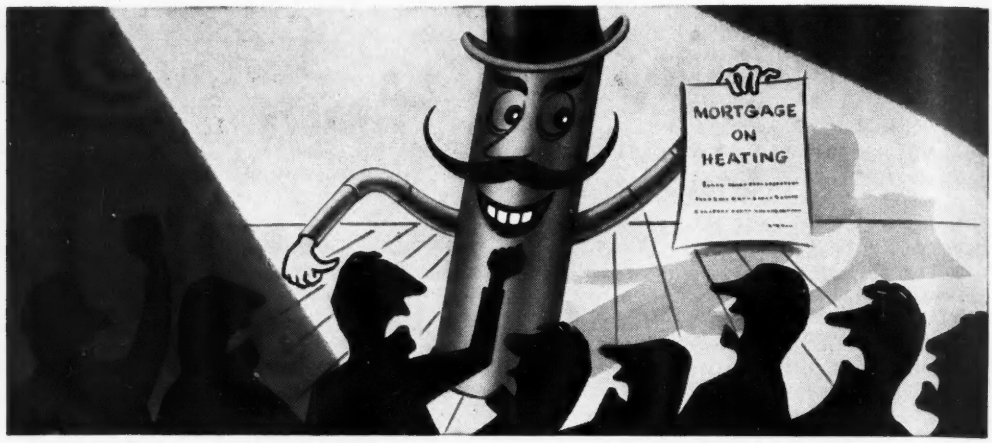
In the design of a reactor for a magnetic amplifier, the problem arises of making a choice of the core and the type of magnetic material to be used. Since it is not practical to measure core characteristics under actual amplifier operating conditions in production, these conditions are best simulated in a core tester. A recent report describes a method which has proved its merits in practice. The core test consists of using a half-wave rectified current to drive the core flux to saturation once each cycle. A d.c. control current resets the flux during the off half-cycle, and an average-sensitive voltmeter measures the voltage in a pick-up winding. The correlation between core test and amplifier operation rests on the basic assumption that a core, when operating in an amplifier, reduces the volt-time integral across the load by absorbing or supporting a value of volt-seconds proportional to the flux changes in the core. Under this condition, the voltage induced in the pick-up winding of the test instrument corresponds to the voltage induced in the amplifier output winding when the core controls the load voltage and, under conditions of equivalent applied control magnetizing force, the amplifier output can be calculated from core-test measurements.

• *PRECISION CONTROL OF HIGH-PRESSURE VALVES BY MAGNETOSTRICTION*

In the pressure range of 30,000 psi, valves having a cone seating on the edge of a circular hole produce considerable flows when the cone is lifted from the seat over only a fraction of the seating circle. The valve stem must therefore be positioned very accurately if accurate flow control is to be obtained. A novel type of valve-operating device, designed to achieve accurate flow control, is based on the principle of magnetostriction, by means of which it has been found possible to position valves to an accuracy of better than 10^{-6} in. It is claimed that, in fact, precision flow measurements made on this valve have shown the repeatability of flow settings to be as good as or better than the accuracy of the flow instruments used, i.e., 1% of the flow rate, indicating a repeatability of valve position of the order of 0·1 micro-inch. In one typical design, the total stroke of the valve caused by magnetostriction and by pressure acting on the valve stem is of the order of 0·003 in. A pneumatic operator is used to position the valve stem to about the centre of its operating range by balancing the hydraulic force acting on the valve. Mechanical screws cannot be used for this adjustment, because screws with a pitch fine enough do not have the strength to absorb the high forces involved. In the original application, the valve was powered by full-wave rectified alternating current with no filtering, except that of the inductance of the magnetostrictive driving coil. It is considered that better resolution in pressure let-down control can be obtained by shunting a capacitor across the driving coil to resonate at ripple frequency.

• *ELECTROCHEMICAL ELECTRONIC DEVICE*

According to a recent announcement, a novel electrochemical device is being developed which eventually may take the place of thermionic tubes and transistors. The operating principle of this low-power high-sensitivity device is said to be simple. Electric current is generated by the movement of ions between electrodes in a chemical solution, after being excited initially by a dry-cell battery. The current is then sustained and varied through stimulation of the unit by either temperature, pressure, light, sound, or acceleration. It is reported that test models of an electrochemical flight integrator have already been produced and demonstrate the simplicity and accuracy of the new device. This particular application is based on the inertia principle, and, once started in motion in one direction, it possesses what amounts to a memory of its original course, instantly sensing any directional change in three dimensions. The integrator mechanism consists of a small cylinder divided into two sections by a porous ceramic filter, with two electrodes immersed in a potassium iodide solution. Any change in direction of movement produces a measureable change in current output, and this change, in turn, activates appropriate control devices. It is claimed that electronic integrators in present use are far more complex than the new device. Another control mechanism based on the use of the new device can serve to replace conventional types of thermostats to control furnace and room temperatures. Here, the new instrument detects the rate at which a given temperature change is taking place, rather than sensing a change which has already occurred. The



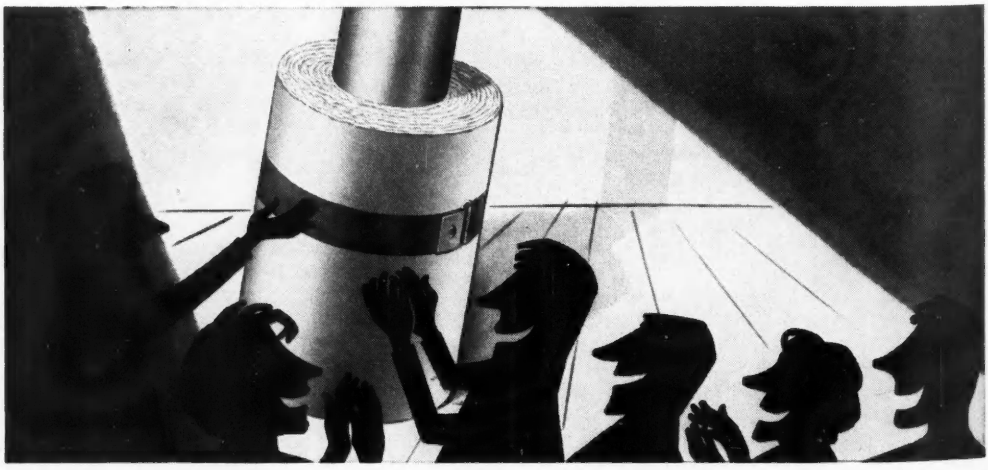
I WAS THE VILLAIN

—HOT WATER PIPE HISSES

"I work in a block of flats. It is my job to carry hot water up to baths and radiators. But they might have called me Luke for all the warmth I used to deliver! I lost most of it on the way! First there was Fred, the boilerman, he used to warm his feet on me; then Mrs. Fred the housekeeper, used to drape her smalls over me. And so I cooled as I climbed. But now that's all changed. I'm decently dressed and decently behaved. Rigid sections of Fibreglass hold me tight — from boiler to tap. Now it's hot radiators and boiling baths for everyone, everywhere. All my own work—with Fibreglass of course!"

FIBREGLASS
TRADE MARK

"Rigid Sections saved my honour" *—HOT WATER PIPE REVEALS*



FIBREGLASS LIMITED · ST. HELENS · LANCASHIRE · ST. HELENS 4224

tendency to overshoot or undershoot the desired temperature range is therefore eliminated. It is reported that the new device can be made sensitive enough to react to the heat of the human body, to practically any light source, or to very low pressure. Another interesting application is in the construction of a cumulative sound-exposure meter, in which the fluid in the electrochemical unit becomes darker with exposure to high-intensity sound. The degree of discoloration then indicates exposure to a predetermined amount of sound.

● *DIRECT GRANULATION OF MOLTEN FERROSILICON*

The direct disintegration of molten ferrosilicon to a fine powder has been achieved in a granulation method developed recently. The process creates rounded or generally spherical particles of ferrosilicon, and granulation is accomplished by the force of a high-velocity jet of water and gas colliding with a stream of the molten metal. The fineness of the particles and the distribution of particle sizes, within limits, are determined by several controllable variables, among which are the relative sizes of the water/gas jet and the stream of molten metal. The roundness of the granules is determined partly by variables such as these and partly by the surface tension of the particular alloy. With ferrosilicon, as much as 50% of the particles pass through a 65-mesh screen, and up to 70% through a 40-mesh screen. The high-velocity jet of water is obtained by introducing the water under pressure into a special nozzle where additional momentum is imparted to it by the expansion of high-pressure gas mixed with the water in the nozzle. The process is considered potentially useful in many cases where it is desirable to eliminate a grinding stage and to proceed directly from molten metal to finely granulated spheroidal material on a high tonnage basis as, for example, in the production of metal powders of controlled composition. It has been suggested that the process may be adaptable to fritting molten ceramic oxides. By this method, it may be possible to break up the frit into particles smaller than those obtained at present and thus reduce subsequent milling.

● *SIMPLIFIED REFRIGERATION SYSTEM FOR TEST CHAMBERS*

By eliminating practically every feature of conventional refrigerating technique other than the basic principle, it has been found possible to construct a refrigeration plant for test purposes which is of truly remarkable simplicity. The novel system has no compressor, condenser, or heat exchanger, and, in fact, no moving parts, except for one valve. Cooling is directly produced by the vaporization of liquefied CO_2 or other gas released into the refrigerated area through the control valve, without the use of heat-exchange coils. The result is said to be exceptionally efficient, with rapid cooling, close temperature control, and highly economical operation. This refrigeration system is reported to be in use for test chambers ranging in size from 1 cu ft to walk-in cold-rooms. These test chambers are equipped with three systems for producing a wide range of environmental conditions, i.e., a refrigeration system to maintain temperatures down to — 108°F with CO_2, and even lower with other gases ; a heating system for temperatures up to 600°F ; and a humidifying system to maintain any desired relative humidity between 5 and 100%. The refrigeration and heating systems are both controlled thermostatically, and another control is provided for relative humidity. In the case of a 32-cu ft test chamber, a room temperature of — 100°F has been reached in 5 min, compared with 1½ to 4 hr with mechanically refrigerated equipment. Because of the design of the refrigeration system and the efficient air-circulating system, the thermostats can operate with a temperature differential of less than 2°F throughout the chamber. The cost of the complete test chamber is said to be about 25% that of conventional test chambers, largely because of the simplified refrigeration system.

● *ULTRASONICALLY TREATED BEER*

Experiments connected with the ultrasonic ageing of whisky are well known. Now, however, a recent report makes it appear quite likely that, in the expansion of bottling and canning facilities in breweries, ultrasonic equipment will play an important part. Beer and ale are basically food products, and shelf life is an important factor in packaging them. Whereas, with kegged beer and ale the product is consumed in a relatively short time, the bottled or canned product may not be consumed for months. It is recognized that exposure to air or the presence of occluded air shortens shelf life considerably, since atmospheric oxygen oxidizes or denatures some of the protein groups dissolved in beer. This oxidation tends to make the protein less soluble and hence come out of solution, with the result that the product becomes hazy and acquires a fruity or estery taste. From experience it has been found that about 1 cc of air in every 5 oz of beer or ale is acceptable, and it has now been established that the air contained in freshly filled bottles can be more effectively removed by subjecting them to ultrasonic vibrations than by conventional methods of agitation. A recently developed ultrasonic beer de-aerator or beer foamer consists of a 250-W generator and bias supply connected to a magnetostrictive transducer, a shoe

Service is a Tradition . . . .

We have always regarded the provision of a complete service, from design to finishing, as a major necessity between the conception of a product and its delivery to a market. That service, in the supply of zinc and aluminium die castings, is now traditional with us. Add to it our years of experience and we can present a very good reason why we are the largest pressure die casting organisation in the country, serving the needs of over 700 customers in 30 industries.

THE WOLVERHAMPTON DIE CASTING COMPANY LIMITED

GRAISELEY HILL WORKS · WOLVERHAMPTON · TELEPHONE : 23831/6

being mounted on the end of the transducer to accommodate the bottles on the filling machine. The ultrasonic generator is basically a tunable 22-kcs oscillator and power amplifier with an output of 250 W, and the transducer has a laminated oxidized-nickel core stack with a winding around the long arms. A permanent magnet supplies a biasing flux. The transducer and shoe are made of stainless-steel components, with the exception of the nickel stack, while teflon-insulated wire is used in the transducer. It is stated that the apparatus can also be used for accelerating the ageing of wine.

● *NEW ALUMINIUM-MOLYBDENUM-TITANIUM ALLOY*

It is reported that a new aluminium-molybdenum-titanium alloy has been developed and displays remarkable strength characteristics both at room and elevated temperatures. The alloy contains 6·5% aluminium and 3·75% molybdenum, the balance being titanium, and is characterized by improved time-temperature-stress stability, with deep hardenability and excellent heat-treated properties. Tests at elevated temperatures have shown that highly stressed samples at between 600 and 1000°F have undiminished strength and retain good ductility at subsequent exposure to room temperature. It has also been found that, after appropriate heat treatment, samples of 2 in. in thickness display a tensile strength of 160,000 psi without any loss in ductility. It is considered that the new alloy shows considerable promise in aircraft applications and appears to be particularly suitable for jet-engine discs and blades, and, in general, for light-weight airframe forgings, fasteners, and similar parts. Extensive tests on the machining properties of the material are reported to be in progress.

● *FORCE RELATIONSHIPS IN THE MACHINING OF SULPHUR-ENRICHED CARBON STEEL*

A knowledge of force relationships during metal cutting is essential for an understanding of the properties of a metal as they affect machining operations. Force determinations, together with chip measurements, provide the necessary data from which the mechanical quantities affecting machinability can be determined. When the controlling properties of the material are known, the problem of improving machinability can be approached more rationally than by reliance on purely empirical data. In a recent investigation the beneficial effects of sulphide inclusions, i.e., of sulphur content, on machinability were studied. Force relationships were investigated in a constant-pressure lathe, as well as in a conventional lathe. The constant-pressure lathe has been used exclusively for evaluating the machinability of low-carbon free-cutting steels. Machining in this lathe differs from normal machining processes in that the feed is not fixed, but is dependent on the lateral force exerted on the tool and on the resistance of the workpiece to tool penetration. Tests in the conventional lathe were carried out to determine force relationships for machining with predetermined feeds, and were conducted on low-carbon steels containing various amounts of sulphur from 0·025 to 0·25%. In these tests, a wire-resistance strain-gauge dynamometer was used to measure the forces acting on a high-speed tool for various cutting conditions. In the constant-pressure test, sulphur additions increased the feed obtained with a given thrust load. The addition of sulphur reduced the forces acting on the tool for equivalent feeds in both test lathes. It was found that the decrease in friction and strain reduced the work required for removal of a unit volume of metal during machining. The results of tests with conventional lathes generally corroborated those obtained in the constant-pressure lathe.

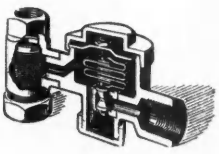
● *EFFECT OF MAGNETIC FIELDS ON THE ACCURACY OF STRAIN-GAUGES*

It has been observed that serious errors in strain measurements on electrical machines and magnets, particularly those used in nuclear research, can result from the effect of magnetic fields on the wires of resistance strain-gauges. It is well known that a current-carrying ferromagnetic conductor changes its resistance under the influence of an external magnetic field. This magneto-resistive effect may be either positive or negative, depending on the material of the conductor and its orientation with respect to the magnetic flux, and, when allowed to unbalance a strain-gauge bridge, it produces a spurious indication of strain. When the magnetic field is parallel to the conductor, resistance increases with field strength up to some saturation value of flux. At extremely high fields, resistance may tend to decrease again. However, when the field is normal to the conductor, and hence to the current, resistivity usually decreases with increasing fields. Externally applied strains also affect the resistivity of the material. This elasto-resistance forms the basis for the use of wire-resistance gauges for the measurement of strain. Elasto-resistive and magneto-resistive effects are interrelated and, if the strain is large enough, the magneto-resistive effect in the case of positive magneto-resistive materials will become negligible. With negative magneto-restrictive materials, the converse is true. An investigation on the influence of the magneto-resistive effect on strain-gauges has recently been carried out, the strain-gauge wire materials investigated including elinvar (57% Fe, 34% Ni, 9% Cr), constantan, and a 92% platinum

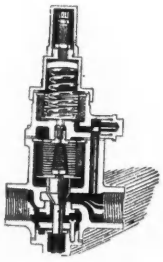
"the moon is made of green cheese"

SURELY a heading for a fairy tale! Of course it is! It appears here to emphasise that far too many fables are used in advertising instead of facts—personal views of the advertiser and statements in the superlative are made to look like universally acknowledged truths. That's what makes advertising suspect in the minds of so many.

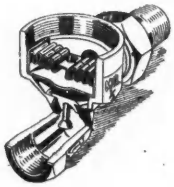
MIL Steam Fittings have so much to recommend them that the manufacturers have no need to over-state or exaggerate. Because of this, every word in their advertising is to be believed—the care and precision at each stage in the making of their products is confirmed by thousands and thousands of satisfied customers and upheld by a two year guarantee.



MIL STEAM TRAP

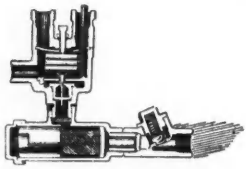


MIL REDUCING VALVE



MIL LOW PRESSURE STEAM TRAP

Our Technical representatives are at your service, meantime, may we send you full details?



MIL WATER HEATER CONTROL

MIL

STEAM FITTINGS

MIDLAND INDUSTRIES LIMITED · HEATH TOWN WORKS · WOLVERHAMPTON

London Office: 28, Victoria Street, S.W.1. Scottish Office: 69, St. Vincent Street, Glasgow, C.2.

alloy with 8% tungsten. An important result of these tests was that only the elinvar gauges showed the magneto-resistive effect. Wherever possible, the less strain-sensitive constantan gauges are therefore more suitable for applications around magnetic fields.

● *MAGNETOSTRICTIVE VIBRATORY ROCK DRILLING*

A study of the fundamentals of the process of rock drilling has shown that the rate of penetration of a bit into rock depends directly on the mechanical power input into the rock. In both rotary drilling and turbo-drilling, the mechanical power input to the rock is developed by the rotation of the bit, and the torque reaction to rotation results from the sinking of the teeth of the bit into the rock, their penetration being produced by thrust load. Greater mechanical power is developed at the rock by turbo-drills, because they rotate faster. It would also seem reasonable to increase the mechanical power input to the rock at the lower rates of rotation by increasing the coupling of the bit to the rock, so that a greater torque reaction is developed when the bit is rotated. Since the static load on the bit in rotary drilling and the thrust force in turbo-drilling are both limited by practical considerations, the increased coupling must be obtained in some other way, such as vibrating the bit. A vibratory drilling machine, driven by a magnetostrictive transducer, is reported to be in course of development. The vibration frequency employed is 300 cps, and it is stated that rates of penetration of two to three times those obtained with rotary drilling have already been achieved with experimental drills. Since the magnetostrictive motor can produce reciprocating motion without the use of relatively sliding or rolling parts, it offers a distinct advantage in operation in an abrasive fluid under pressure. Several other types of vibratory drills are said to be under development, in one of which the bit is vibrated at mains frequency by means of turbine-rotated eccentric weights driving a resonant steel column.

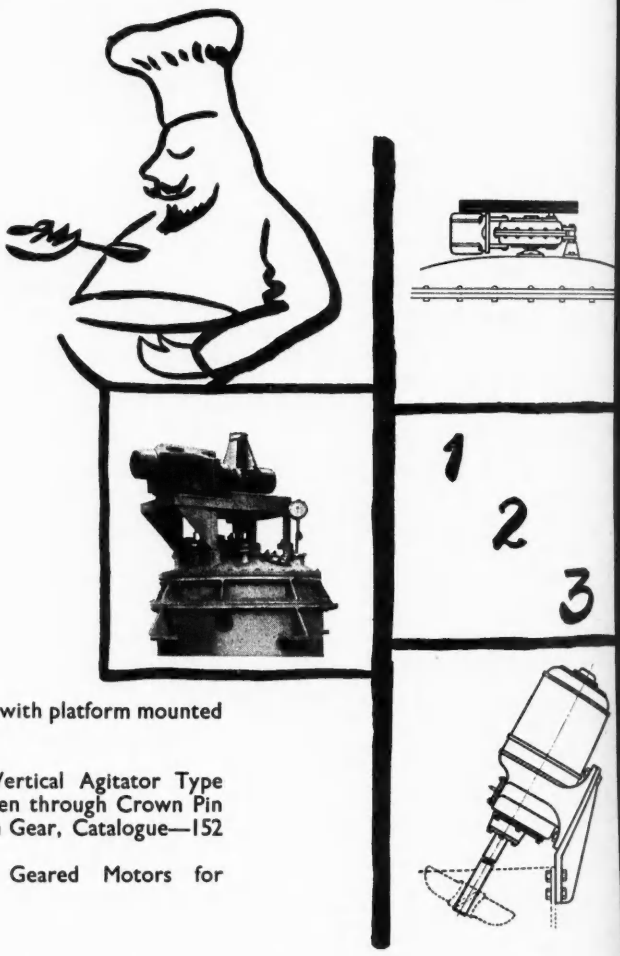
● *CORRELATION ANALYSIS OF TAPE-RECORDED DATA*

To apply automatic control properly, it is necessary to know the frequency-response characteristics of the system. These characteristics are not easily calculated for complex systems, and usually have to be determined experimentally. Unfortunately, many large physical systems cannot be disturbed by the usual methods, which require the use of significantly large step, impulse, or sinusoidal inputs. If an automatic control system does not function properly, it may easily do more harm than good, and accurate prediction of its behaviour under service conditions is therefore vitally important. The most powerful technique for determining the frequency response of a control system so far developed makes use of the auto- and cross-correlation functions of two random variations in the system. Except for one analogue method, employing a dual-function generator, correlation functions of recorded data have up to now been generated either by a general-purpose digital computer or by slow and tedious manual routines. Now, however, a special magnetic-tape scanner has been developed, capable of effecting generation of the correlation functions automatically in a few minutes. Utilizing rotating heads to read a stationary section of tape selected from its reels for analysis, the scanner can be used with suitable display equipment to permit a quick look at recorded information or to scan volumes of data for significant sections at high or low speeds. In the latter case, it provides a precision output for detailed analysis. Other applications include determination of the time of an event ; determination of the deviation limits of telemetering ; the display of information on large screens ; and the display of transient phenomena for detailed study.

● *COMBINED SPARK-PLUG AND STRAIN-GAUGE FOR CYLINDER-PRESSURE MEASUREMENTS*

With the use of higher compression ratios, cylinder heads have become more compact, leaving little room for test ports of any kind. In the case of new production models, the introduction of an additional opening in the cylinder head is practically impossible, because of the added complications in water-jackets and valve mechanisms. However, a pressure-sensing device built into a standard spark-plug has now been developed and provides a simple solution to the problem. A flexible pressure receiver in the form of a hexagonal sleeve is installed in the electrode cavity between the electrode and the plug body. Six small holes are drilled radially through the plug body perpendicular to the six flat surfaces on the pressure receiver. Pins are secured to each of these surfaces and project through the small holes in the plug body. Insulating terminals are attached at the ends of each pin, and the strain-gauge winding is stretched from insulator to insulator in several turns about the spark-plug body. Strain-gauge leads are carried in a steel tube which supports an electrical connector several inches above the plug ignition terminal, and a metal shield, protecting the strain-gauge element, is provided. Changes in cylinder pressure cause the flat faces of the pressure receiver to deflect, these deflections being transmitted to the strain-gauge wire by means of the connecting pins, so that the gauge is tensioned in accordance with the diaphragm deflections.

MIXING
in the best circles



Three typical applications of CROFTS MIXER DRIVES

1 Shaft Mounted Gear Unit with platform mounted motor, Publication 655

2 Radiation Fan Cooled Vertical Agitator Type Worm Gear, motor driven through Crown Pin Flexible Coupling Worm Gear, Catalogue—152

3 Ritespeed 'Efficiency' Geared Motors for inclined mounting

Crofts

CROFTS (ENGINEERS) LIMITED

BRADFORD 3 YORKSHIRE

Tel: 65251 (20 lines) Grams: 'Crofters Bradford Telex' Telex 51-426

BRANCHES AT: Belfast, Birmingham, Bristol, Cardiff, Dublin, Glasgow, Leeds, Liverpool, London, Manchester, Newcastle, Northampton, Nottingham, Sheffield, Stoke.

THE ENGINEERS' DIGEST
REVIEW OF WORLD ENGINEERING PROGRESS
VOL. XVIII No. 9 SEPTEMBER, 1957

An Appraisal of Ceramic Cutting Tools

By R. C. BREWER

HARDNESS and toughness at cutting temperatures must be the principal properties of any tool material, and experience has indicated that one property is increased only at some expense of the other. Lack of toughness can be offset, to some extent, by tool geometry, and consequently the initial governing factor in seeking new tool materials has nearly always been hardness.

The hard particles of a tool material need to be small, in order to confer resistance to abrasion, and the first stages of research on a new tool material include investigations into the extent to which this factor can be controlled. Materials which offer possibilities in this direction are various carbides, nitrides, borides, and oxides. Table I gives details of some of these materials, together with their Knoop micro-hardness, because macro-hardness indenters are of little use in testing very hard brittle materials.

At present, the borides and oxides have shown most promise. The borides investigated have been titanium diboride, molybdenum diboride, and a ternary boride of molybdenum and nickel ; tests so far do not put these borides beyond the carbide range as regards cutting speed, but they are still in the development stage, and improvements, particularly with regard to reduction in grain size, could alter this picture. The oxides which have a potential interest as tool materials are those of aluminium, beryllium, thorium, and zirconium. Of these, aluminium oxide is the hardest and has been most developed ; tools and tips made from this material are now commercially available in England, the U.S.A., and Western Europe, and have been used in Eastern Europe for almost five years. It is to these aluminium oxide tips that the greatest part of this survey will be devoted, although any relevant information on other new materials will be given, where appropriate.

The idea of using aluminium oxide as a tool material appears to date from the turn of the century but, as a practical proposition, the history of such tools commences much more recently with the 1938 patent of the Degussa Company in Germany although there are reports of tests with ceramic cutting tools by Siemens and Halske in the early 1930's.

The tools which are now covered by the term " ceramics ", are, in essentials, corundum, i.e., the stable alpha form of aluminium oxide or alumina. It is possible to distinguish, however, two clearly defined branches of this tool family. The first consists of tool materials which are almost pure aluminium oxide (98% or more) and may rightly be called " sintered oxide " tools, while the second consists of tool materials to which alloying elements have been added in order to achieve some specific purpose ; such materials may contain about 90% aluminium oxide and are becoming known, by general usage, as ceramics.

It is important to distinguish between the very small amounts of secondary alumina or magnesium oxide which are added to sintered oxide tools and the relatively substantial additions of such compounds as chromic oxide in ceramic tools. In the former case, the object is to achieve a better uniformity of texture, so that the tool performs better than a pure oxide tool ; in the latter case, some investigators have claimed that the chromic oxide (alternatives are ferric and titanium oxides) increases the strength and hardness of the alumina. It is true that, as with most metals, where the alloy is stronger than its constituents, the mixture of the two isomorphous oxides Al_2O_3/Cr_2O_3 is harder than pure corundum. There exists, however, a controversy as to whether such additions are desirable, this controversy arising from the fact that ceramic tools do not appear to exhibit a correspondingly increased performance in practice over sintered oxide tools.

Both ceramic and oxide tools are prepared from alumina powder which is first ball-milled to a suitable size. Before it can be " worked ", however, it is necessary to add binding and plasticizing agents. The material can then be cold-worked by slip-casting, extrusion, or dry-pressing, this latter being possibly the most general method ; the tips are then dried in an oven and sintered. An alternative to cold-working is the hot-pressing operation in which pressing and sintering are done simultaneously, thus giving an almost 100% density (see later remarks on porosity). In order to confer optimum properties, the sintering temperature should be between 1550 and 1700°C.

TABLE I

Material	Knoop Hardness	Comments
High-speed steel	650–950	
Tungsten carbide	1400–1900	
Aluminium oxide	1900–2000	Commercial proposition for many production jobs.
Titanium carbide	2470	Not yet a commercial proposition.
Silicon carbide	2500	Difficult to form economically into bits.
Titanium diboride	2700	Very low tensile strength with present grain size.
Boron carbide	2800	Loses its resistance at normal cutting temperatures.
Diamond (for comparison)	6500	

TABLE II

Material	Compressive Strength [psi]	Bending Strength [psi]
Tungsten carbide	570,000–710,000	100,000
High-speed steel	540,000–600,000	430,000–530,000
Aluminium oxide	240,000–420,000	35,000–80,000
Beryllium oxide	110,000	20,000
Thorium oxide	210,000	14,000
Zirconium oxide	290,000	21,000

Table II gives details of the compressive and bending strengths of carbide and high-speed steel, compared with the four oxides previously mentioned. Of the oxides, the general superiority of aluminium oxide is evident, particularly in bending strength, which, despite the use of negative rake angles, is still of considerable importance in tool engineering. It is undoubtedly true to say that the bending resistance of carefully manufactured ceramic and oxide tips is good enough for constant loads, but vibrations or sudden changes in load are usually sufficient to cause, or at least promote, breakdown of the cutting edge. An aggravating factor from the point of view of applying alumina-based tips to such operations as milling is that a sudden change in mechanical load is accompanied by a change in thermal conditions, and these materials are sensitive to fracture by thermal shock.

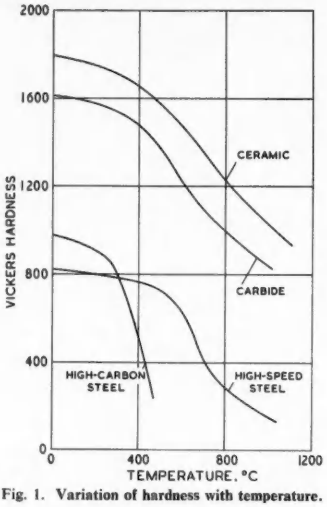


Fig. 1. **Variation of hardness with temperature.**

So far, the discussion has centered on the manner in which alumina satisfies the more important properties required in a tool material. For successful application, however, a critical point is the extent to which these properties are retained at the relatively high cutting temperatures involved. Fig. 1 shows the extent to which the hardness of a ceramic is maintained, and curves have been added for other tool materials, so that a comparison may be made of the relative decreases in hardness with temperature ; it should, however, be noted that the actual values of hardness at room temperature should not be compared, since the figures for a given type of tool material may vary quite considerably with changes in metallurgical composition. It is evident from Fig. 1 that alumina-based tools retain their hardness to approximately the same extent as carbides. The other properties discussed vary in much the same manner.

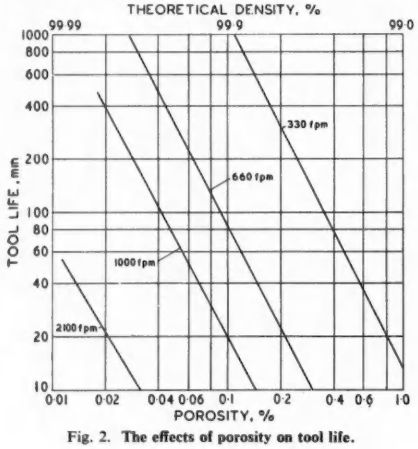


Fig. 2. **The effects of porosity on tool life.**

In the early days of development of ceramics, erratic results were often encountered in performance tests, not only from tip to tip but also from regrind to regrind with the same tip. It has been suggested that, in addition to lack of control in the processing of the material, a contributory cause may well have been that the tool material was being worked very close to its tensile limit, so that the inevitable small changes in cutting conditions might have caused the difference between success and failure.

Porosity and Grain Size

Virtually all alumina-based tool materials contain very small percentages of silica and certain alkalis, thus causing the specific gravity to change from 3·99—the value for corundum. However, for those materials falling into the category previously defined as sintered oxides, the effect is so small as to be negligible, and any observed reduction in specific gravity from 3·99 can be taken as a measure of porosity. This porosity may be in the grain boundaries or inside the crystals but, whatever the origin, its effects are a deterioration in wear resistance and a consequent reduction in tool life, as shown in Fig. 2. It is thus imperative to keep the porosity as low as possible, i.e., the specific gravity as near to 3·99 as possible, and hence, for sintered oxide tools, determination of specific gravity is a convenient test for porosity. In the case of ceramics, however, the effect of the additional elements is usually to increase the specific gravity and, unless manufacture is very closely controlled, it is difficult to utilize a specific-gravity test for porosity ; in such cases it is better to rely on some standard machining test, although this is neither so rapid nor so cheap.

Grain size is also very important and must not only be small but must be capable of good control. It has been claimed that the addition of chromic oxide in ceramics materially assists in controlling grain size. The method of control in sintered oxide tools is usually the addition of secondary alumina (i.e., finely divided) or magnesium oxide.

Although it is frequently claimed that alumina-based tools are chemically inert and thus do not give rise to built-up edges, it has been found that, if the additive constituent of the tool and workpiece is the same, a built-up edge is often formed. The author has found this to occur when machining aluminium and when machining chrome steels with ceramic tools containing chromic oxide, while Tangerman[1] has reported a similar reaction when machining titanium with a titanium boride tool.

Use of Alumina-Based Materials for Practical Tools

Alumina-based materials and certain borides possess sufficient hardness and toughness to interest tool engineers. Certainly, in the case of the alumina-based tools, it may be added that there is such an abundance of widely distributed raw material that it can never be regarded as strategic. Nevertheless, one of the greatest disservices which can be done to these new materials is to proclaim

indiscriminately that they are a panacea for all machining ills and that they will out-perform any conventional tool material on all jobs. A more thoughtful approach, in which the function of newer tool materials is regarded as partially complementary to carbide tools, would lead to a general improvement in many machine-shops.

So far, these materials have been considered without reference to their ultimate function as a means of cutting metals, and the mere fact that they satisfy a list of desirable properties is no guarantee that they will perform well in practice. However, before turning to the results of practical investigations, the forms in which alumina-based tools may be used should be considered. Thus, an obvious procedure might be to " joint " the tips to a shank, but it must be recalled that these tips are non-metallic and the usual metal-jointing methods are of little use. Special methods have been devised for making a ceramic-to-metal joint but, for heavy cuts, none of the present methods seems to be entirely satisfactory. Also, the present tendency to implement the throw-away concept is gaining ground largely in the type of work where alumina-based tools can make headway, and the call for jointed tips is not likely to be so great.

Alternatively, the tip may be clamped mechanically by two quite distinct methods, either of which lends itself to the throw-away concept. For " lozenge " or " wafer " tips, clamping is performed on the top surface of the tip by some variant of toolmaker's clamp, and it has been stated that such tips should rest on a carbide shim or pad, though this contention appears to be controversial. With the longer " prism " bits (sometimes called " slugs " in the U.S.A.) a slit-head type of tool-holder is used, and clamping pressure is applied to the sides of the bit. Tool-holders of both these types are available from several makers in the U.K., and, though introduced for carbide blanks, are equally well suited to ceramic and sintered oxide blanks.

Where alumina-based tips have to be ground, it is preferable to use diamond-bonded wheels, and a good supply of coolant is an advantage in preventing wheel loading ; grinding with green wheels is not generally satisfactory. Final lapping is a material advantage in improving overall performance, and it is now fairly well established that a small negative rake land of about 0·010 in. at the cutting edge is exceedingly beneficial, especially in preventing chipping of the cutting edge when the cut is started.

The question of tool geometry is simplified to some extent with throw-away tips which use all cutting edges, because the rake angle must be negative, the wedge angle of the tool is constant (at 90 deg.), and the included angle at the tool tip is limited to a few standard values, say 60, 90, or 120 deg. for triangular, square, or hexagonal tips respectively. The side and back rake angles are normally equal, and the commonest values are — 5 and — 7 deg., although the Russians have used negative rake angles as high as 10 and 12 deg.

The chief point to be settled now is the side cutting-edge angle ; with the long prism bits requiring a slit-head tool-holder, unless the user is prepared to make his own tool-holder, the choice is effectively restricted to 15 and 45 deg., these being the general standard figures. It is an easier task to make tool-holders for lozenge or wafer tips, thus giving rather more freedom in the choice of the side cutting-edge angle. The actual value of this angle in machining with alumina-based tools is, as is often the case, a compromise ; from the point of view of easy entry into the work, it should be fairly high, e.g., tending to 45 deg., but, in order to reduce chatter, particularly with high depth/feed ratios, it should be low. Since chatter is to be avoided at all costs, the best rule is to adopt the smallest side cutting-edge angle giving satisfactory entry of the tool into the work. Occasionally, the particular application will settle the point, e.g., on tracer-controlled lathes, where a zero side-cutting-edge angle may be necessary.

There is one further point, over which there is much controversy, i.e., the nose radius. Early articles often stressed that this should not be greater than $\frac{1}{32}$ in., doubtless based on the fact that chatter tends to be more troublesome at large nose radii. However, this danger is often more apparent than real, and nose radii greater than $\frac{1}{32}$ in. can be beneficial.

The triangular, square, and hexagonal lozenge tips, which yield 6, 8, and 12 cutting edges respectively when used as discussed above, can be used as positive-rake throw-away tips by forfeiting half the number of cutting edges. For anything more than finishing work, however, the use of positive rake angles should be restricted to soft materials, chiefly non-metals such as impregnated plastics and graphite.

Application of Alumina-Based Tools in Practice

As mentioned previously, the final arbiter of a new tool material is its performance in practice, which should be based on experience and not on the results of preliminary tests in which most of the machining parameters are chosen almost arbitrarily. This may appear self-evident, but it is probably one of the greatest contributory factors to such statements as " this new tool material is useless in our shop ".

Basically, a tool material can be assessed when information is provided on (a) resistance to wear ; (b) tool life when machining various materials ; (c) power requirements (or tool-force relationships) ; and (d) surface-roughness tests.

(a) *Resistance to Wear* :—

Before considering the subject of resistance to wear, it is of interest to examine the possibility of failure occurring when the tool enters the cut or (equally important when turning short lengths) when the tool comes out of the cut. This problem has been investigated by Moore and Kibbey[2], who used a statistical approach and multi-variable techniques, more common in industrial engineering than in mechanical engineering. The chief disadvantages of tests in which all variables except one are held constant are the very large number of tests required, and the implicit assumption that, having discovered the information for some given value of a particular variable, this law will hold for all other values of this variable. The first disadvantage leads to a tendency to draw curves through too few points and to indulge in unjustifiable extrapolations. Moore and Kibbey chose to vary three parameters at a time and in three sets of experiments, covered nine variables in all. In fairness, it must be pointed out that the computation work in multi-variable techniques is quite considerable.

From the tests of Moore and Kibbey, the following suggestions may be offered for avoiding breakdown when entering or leaving the work :—(1) Where vibrations permit, a large nose radius should be used ; (2) in general, a decrease in feed and an increase in depth of cut (for the same chip area) will give less tendency to failure ; (3) a negative rake land with a width of 0·010 in. or half the feed, whichever is the greater, should be honed

on the cutting edge ; the optimum value of the rake angle for this land appears to be about — 45 deg.

Assuming now that the cut has been started successfully, flank and/or face wear may take place to some arbitrarily defined limit or, at some stage, there may be a sudden cracking near the cutting edge followed by complete breakdown. The only instances where crater wear has been observed have been when cutting chrome steels with ceramic tools containing chromic oxide.

Certain materials appear to cause, or at least tend to cause, breakdown of the cutting edge but, apart from these, the chief causes of breakdown are bad cutting conditions (e.g., too high a feed, wrong selection of side cutting-edge angle, etc.) or lack of rigidity in the general system. If these points receive careful attention, there is no reason why failure by complete breakdown should be anything but the exception.

With regard to the question of how wear increases with cutting time, there is a fairly well established pattern of events. There is an initial period, of a few minutes at most, when wear rate is high, after which it decreases considerably to a value dependent on cutting conditions. This new wear rate may continue almost indefinitely or, for more arduous cutting conditions, may increase steadily. Fig. 3 shows a typical set of wear curves for various feeds and also demonstrates a phenomenon peculiar to alumina-based tools, i.e., the presence of short, or sometimes comparatively long, periods when no discernible wear takes place. So far, no explanation of this phenomenon appears to have been advanced.

One factor which has been established is that the possibility of complete breakdown during cutting increases with the amount of wear that has taken place. Thus, it is generally advisable to impose as the amount of permissible wear before an alumina-based tool is reground or re-indexed a lower figure than the 0·030 in. customary for carbide tools. Several figures have been proposed, and it appears that the actual amount is a function of the material being cut but, in order to give some guide, the author suggests about 0·016 to 0·018 in.

(b) *Tool Life* :—

When a shop is committed to a definite rake angle and to one or two side cutting-edge angles, the chief machining parameters of which tool life will be a function are cutting speed, depth of cut, and feed.

With regard to the variation of tool life T with cutting speed V, the normal power-law relationship (VT^n = constant) holds above a certain cutting speed ; this speed is dependent on other factors, but may broadly be stated as 150 to 300 fpm for carbon steels. Below this speed,

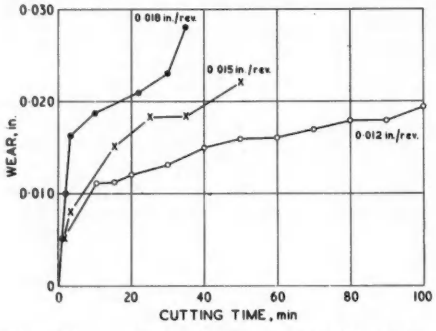


Fig. 3. Wear as a function of cutting time with different feeds.

wear due to chipping of the cutting edge is very pronounced and leads to a reduction in tool life with a decrease in cutting speed. Fig. 4 shows such a tool-life cutting-speed relationship, as obtained by Zhikharev.[3]

The variation of tool life with depth of cut d and feed f also seems to follow the normal power-law relationship, but there is some evidence to show that there may be a change in the index relating feed to tool life for high values of feed, e.g., above 0·030 in. per revolution. Thus, the composite tool-life relationship may be expressed as $VT^nf^ad^b$ = constant, depending on the material cut, where n, a, and b are constants for certain ranges of the variables. Fortunately, these ranges encompass the normal practical limits for these variables, i.e., the changes in n at low speeds and a at high feeds are not important obstacles to setting up a generalized tool-life equation, because low speeds and high feeds are not normally good practice with alumina-based tools.

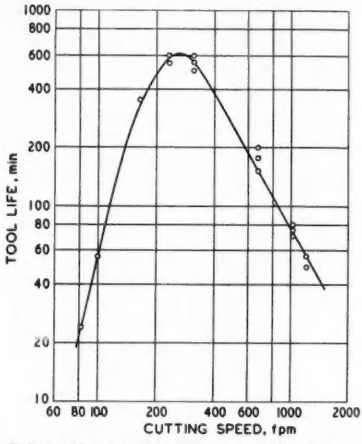


Fig. 4. Relationship of cutting speed to tool life when machining a 50-ton carbon steel.

Given the data from a series of tool-life tests, it is now quite a simple matter to express the generalized tool-life equation in nomographic form for a specific material cut. For one nomogram to hold for several materials cut, n, a, and b would either have to be exactly the same, or the variation would have to be within acceptable limits. The author has found, from his own tests and the data published, that the variations in n, a, and b are within reasonable limits, and has constructed the nomogram shown in Fig. 5. Repeatability in tool-life tests is of the order of $\pm$ 10% ; consequently, this nomogram cannot be expected to predict tool lives to a fine accuracy, though it should be useful in the often difficult, yet very essential, task of making an initial estimate of cutting speed, feed, and depth of cut. It may be noted from Fig. 5 that the cast irons and molybdenum steels have been subdivided according to hardness. It has been suggested, at least by implication[4,5], that a more general tool-life equation exists in which the " material constant " term may be replaced by a hardness term. The author has not found this to be a general truth, but rather a limited truth for cast irons and molybdenum steels treated as two separate groups. It is possible that, if facilities existed, it could be shown to be true for other groups of alloys. Nevertheless, even within the range of alloy steels alone, published information shows that hardness does not uniquely determine tool-life characteristics.

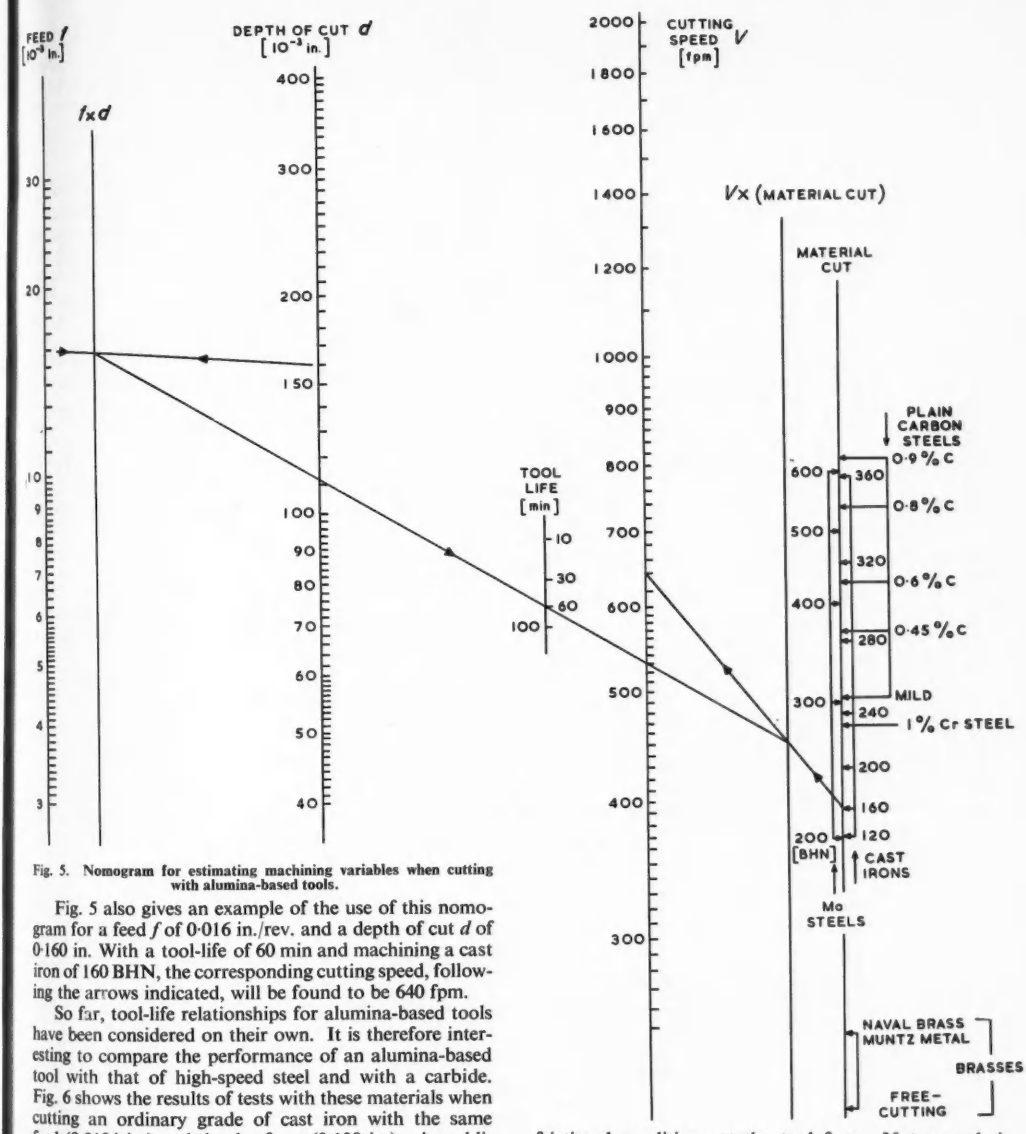


Fig. 5. **Nomogram for estimating machining variables when cutting with alumina-based tools.**

Fig. 5 also gives an example of the use of this nomogram for a feed f of 0·016 in./rev. and a depth of cut d of 0·160 in. With a tool-life of 60 min and machining a cast iron of 160 BHN, the corresponding cutting speed, following the arrows indicated, will be found to be 640 fpm.

So far, tool-life relationships for alumina-based tools have been considered on their own. It is therefore interesting to compare the performance of an alumina-based tool with that of high-speed steel and with a carbide. Fig. 6 shows the results of tests with these materials when cutting an ordinary grade of cast iron with the same feed (0·0104 in.) and depth of cut (0·100 in.). An additional curve is included, showing comparable results for a ternary boride of molybdenum-nickel.

(c) *Power Requirements and Tool Forces* :—

Almost all the power absorbed in cutting is used (a) in the work of shearing the material at a comparatively high strain rate, and (b) in overcoming the resistance to relative sliding at the chip/tool interface. With regard to the work of shearing the material, at first sight there appears to be no reason for any variation at all with different tool materials, but it should be remembered that the shear strength of the work material is not a unique property and depends considerably on temperature and strain rate, both of which may be altered by a change in frictional conditions at the tool face. Not enough is known of the true fundamentals of metal cutting to permit a theoretical prediction of these effects, and recourse must be had to experimental methods. Shear work is dependent on two factors, i.e., the shear strength of the material (under the physical conditions prevailing), and the shear strain (which is modified considerably by the compressive stress acting on the shear plane).

Investigations by the author suggest a decrease in shear strength at higher cutting speeds, but a recent paper by Schmidt and co-workers[6] gives a slight increase over much the same range of cutting speeds. The author and Schmidt are, however, in agreement that a substantial reduction in shear strain occurs with an increase in cutting speed. The result of this combination of effects

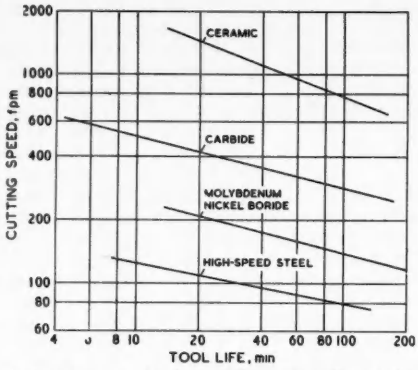


Fig. 6. Tool-life curves showing the difference in performance between various tool materials.

is, in either event, that shear work decreases appreciably with an increase in cutting speed.

The work involved in overcoming resistance to relative sliding at the chip/tool interface depends on the frictional force along the tool face and the chip-thickness ratio. Variation in the frictional force at the speeds employed in machining with alumina-based tools is not significant, but the chip-thickness ratio rises as cutting speed increases, thus giving an overall rise in friction work with increasing cutting speed.

The decrease in shear work and the increase in friction work obviously tend to cancel one another, but there is a slight decrease in the total work of cutting with increasing cutting speed. The frictional conditions with ceramic and oxide tools do not appear to be significantly different from those obtaining with carbide tools under normal conditions, and the overall effect as regards "specific power" [hp/cu in./min] is that the power required for cutting with alumina-based tools is a little less (say 10% at the most) than that required for carbides, but this difference is far less than that which can occur for a given tool material when cutting conditions are changed, particularly for changes in rake angle.

(d) *Surface Roughness* :—

Although some published work includes a qualitative reference to the finish obtained when turning with alumina-based tools, references of a quantitative nature are rare, and comparisons are not facilitated by the fact that, while the Russian report uses the maximum height of asperities as a criterion, U.S. references are to r.m.s. values and British references to centre-line average values. Furthermore, definitions and methods of measurement of surface roughness itself are somewhat arbitrary, and any

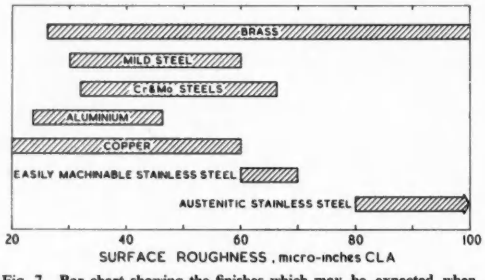


Fig. 7. Bar chart showing the finishes which may be expected when using alumina-based tools.

information must be interpreted accordingly. Fig. 7 is a bar chart showing the range of surface roughnesses (centre-line averages) which may be expected when machining various materials with alumina-based tools having a nose radius of the order of $\frac{1}{32}$ in. Evidently, for optimum finish, the finest feed should be used, but, over the range of finishing cuts, depth of cut has no perceptible effect. Above about 700 fpm, cutting speed has little effect on surface finish, and for mild steel and low-alloy steels, speeds in the range of 1000 to 1200 fpm are quite satisfactory. For non-ferrous metals, the highest spindle speed is likely to be the limiting factor as regards cutting speed. Differences in the finishes produced by carbide and alumina-based tools (under the same operating conditions) are normally slight, and those who are accustomed to thinking of surface finish in terms of carbide tools will not need to alter their views greatly ; in most circumstances, alumina-based tools tend to give a slightly better finish than carbide tools.

The value of surface roughness varies with cutting time in much the same manner as wear (see Fig. 3), at least up to a certain point ; towards the end of the curve, the slope begins to become steeper, and this is usually an indication that the cutting edge is about to deteriorate rapidly.

Conclusion

Ceramic and sintered oxide tools need very rigid conditions for successful application, e.g., tight clutches, finely adjusted bearings, balanced driving dogs, tailstock and slide-ways in good condition, etc. When adopting these tools, some manufacturers have designed new, more rigid tool-holders. Granted these conditions, there is a large field of application for alumina-based tools. Table III lists some of the materials which have been machined successfully with alumina-based tools, together with cutting-speed ranges, which, although wide, serve as a starting point when planning a new run. This table assumes that the components to be machined do not have a hard skin or scale, which is most detrimental to alumina-based tools.

TABLE III

Material	Range of Cutting Speeds [fpm]
Mild steel	1000–1500
Molybdenum steels	600– 900
ditto — heat-treated	350– 450
Cast irons	150–1000*
Nickel steels	250– 600
Brasses	1500–2500
Aluminium alloys	1000 upwards.

* depending on hardness.

Highly ductile materials and particularly those with a high degree of work-hardening seem to be the sphere where alumina-based tools have least success ; in this connection, it is interesting to note that, although an annealed stainless steel was found to be quite unmachinable with an oxide tool, it could be cut successfully at 600 fpm after heat treatment. Indeed, many heat-treated parts can be machined with alumina-based tools in the speed range of 200 to 600 fpm, provided that small depths of cut and fine feeds are maintained.

Owing to their good wear characteristics at small chip areas, alumina-based tools can hold dimensional tolerances well and have been used by some firms to replace certain grinding operations. Whilst at least one American tool manufacturer has marketed an alumina chip-

(*Concluded on page 418*)

The Erosive Effects of Pulsed Electrical Discharges with Weak Currents

By A. Prokes. (From *Czechoslovak Journal of Physics*, Vol. 7, No. 3, pp. 320–326, 378e, and 378f, 13 illustrations.)

The investigation described in this paper is concerned with the erosive effects of pulsed electrical discharges with currents of 50 to 100 mA and with pulse amplitudes of 1000 to 2000 V and durations of 1 to 10 microsec. The possibility of a change in polarity during discharge was eliminated by using a generator which produces positive rectangular voltage pulses, instead of using the usual condenser discharge. By altering the position of the samples, the discharge always occurred at different points, and a trace of the erosive effects produced was obtained.

Investigations of the influence of the medium show that, if the discharge takes place in air, erosion spots, unequal in size, appear on the anode, as shown in Fig. 1. If, however, the discharge falls on the same spot more than once, hardening occurs in nearly all cases (Fig. 2), sometimes without the formation of any observable erosion spots. If distilled water is used between the electrodes, hardening does not appear to take place, and the erosion spots formed are larger and of approximately the same size. This can be explained by the small focusing effect of the discharge channel in air and the larger focusing effect in a liquid medium. If the discharge channel is not sufficiently concentrated, a larger surface of the electrode is affected, and the metal is not melted but merely heated to a high temperature. During cooling and with access of oxygen from the air, hardening takes place. Similarly, with a more diffused discharge channel, energy losses occur, greater in some cases and less in others, with the consequent formation of smaller, unequal erosion spots.

Investigations of electrode polarity show that there is a difference in the character of the spots caused by electro-erosion, according to whether the sample is the anode or the cathode. Fig. 3 shows an example of the type of erosion produced when the sample is the anode, and Fig. 4 when the sample is the cathode, with distilled water as the medium between the electrodes in both cases. Fig. 5 illustrates the type of corrosion produced by a discharge in air when the sample is a cathode. From Fig. 3 it can be seen that, when the sample is the anode, the eroded area has the shape of a round crater, while Figs. 4 and 5 show that, when the sample is the cathode, the erosion spots have an irregular shape, as

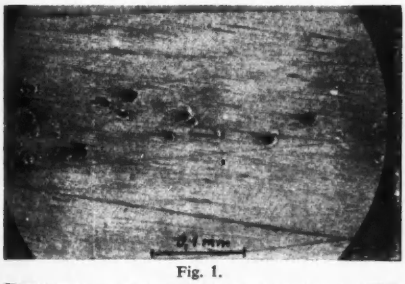


Fig. 1.

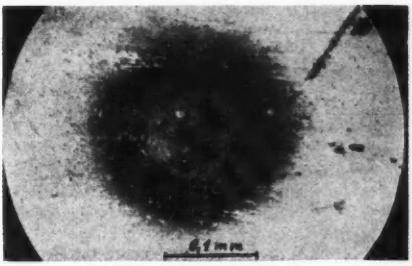


Fig. 2.

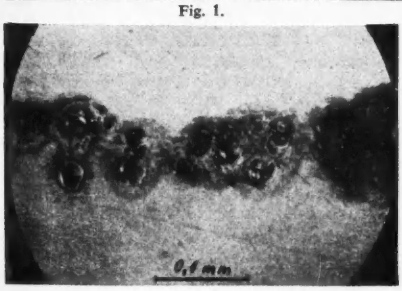


Fig. 3.

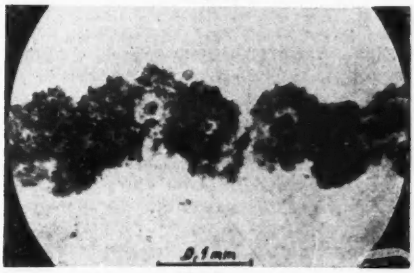


Fig. 4.

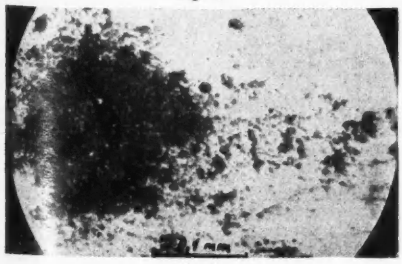


Fig. 5.

Fig. 6.

though metal were sprayed on the cathode from the other electrode. The production of craters can be explained by the fact that, with the sudden slowing down of electrons, a source of heat of very small dimensions is produced, causing melting of a certain volume of the metal. At the same time, part of the metal rapidly evaporates and, as a result of the sudden impact of the evaporated metal on the cathode, the latter is also disturbed.

By using a pentode as a current limiter, much smaller and more regular erosion spots were obtained, as shown by the example in Fig. 6, in which the sample is the anode. The shape of the crater indicates that the material is ejected in the liquid state and confirms the concept of a short-time source of heat of very small dimensions. The melted metal is ejected radially as a result of the pressures produced during decomposition of the plasma. A ridge is thus produced at the edge of the crater. In addition, a small mound is formed in the centre of the crater, and this can be explained by the fact that the molten metal is probably also pulled out perpendicularly to the surface of the electrodes in the form of a drop. During this process, however, capillary forces tend to preserve the cohesion on the drop with the rest of the electrode material, thus producing a small mound at the spot where the drop is pulled.

GERMANY

New Oxide-Layer Resistors with Negative Temperature Coefficients

By P. WALTER. (From *Elektrotechnische Zeitschrift* (*E.T.Z.*), Edition A, Vol. 78, No. 14, July 11, 1957, pp. 500–504, 14 illustrations.)

As a further development of research initially carried out by American glass manufacturers for the production of electrically heated windscreen panels[1], similar investigations have been undertaken in Germany with a view to determining the electrical and thermal behaviour of electrically conductive oxide layers. As a result of these investigations, a new type of resistor with particular properties has been developed. The translucent layers of metal oxide are formed by solutions of cadmium, indium, or tin salts decomposed by hydrolysis on the heat-radiating surface of a glass or ceramic body. The electrical conductivity of such layers is surprisingly high and can be increased by adding other metal oxides. Furthermore, systematic investigations by the Degussa Co., of Hanau, have shown that, by altering the composition and manufacturing conditions, the resistance/temperature characteristic can be varied within wide limits.

The Degussa resistors consist of a ceramic base, an electrically conductive layer, and terminal connections. Between the layer and the terminal connections (clips or caps), a further layer of conductive silver is provided, to reduce contact resistance. Generally, the resistive layer is a mixed oxide of tin and antimony (tetravalent tin and partly trivalent antimony), with extremely good properties as regards mechanical strength, chemical stability, and adherence to the ceramic base[2]. The layer, which has the same hardness as quartz, is, together with the terminal fittings, covered with an insulating varnish for protection against mechanical damage and excessive humidity.

The resistive layer can be applied by spraying, dipping, or vapour deposition. In all cases, however, the temperature of the ceramic base must be above 400°C during the deposition process. The layer thickness increases nearly linearly with the duration of the deposition process, as shown in Table I, in which t = deposition period [sec], h = layer thickness [microns], and ρ = specific resistance $\times 10^{-4}$ [ohm-cm].

TABLE I. PROPERTIES OF SnO_2/Sb_2O_3 LAYER RESISTORS AS FUNCTIONS OF THE DURATION OF DEPOSITION.

t	h	ρ	Colour
20	0·4	9·2	Greyish-white
40	0·8	7·7	Light-grey
80	1·6	7·2	Medium-grey
160	2·8	6·5	Dark-grey
320	7·1	6·0	Black

Deviations from proportionality are due to cooling of the specimens, when the layer deposition process has been extended over a long period. The colour becomes darker with increasing layer thickness. The specific resistance shows a slight dependence on layer thickness, which is probably also due to temperature fluctuations during the process, as well as to surface roughness.

SPECIFIC RESISTANCE AND TEMPERATURE COEFFICIENT

The required value of resistance can be obtained by selecting the correct layer thickness. Moreover, as shown in Fig. 1, which is based on data by Mochel[1], the "standard" resistance of SnO_2/Sb_2O_3 layers is dependent on the Sb_2O_3 content. An addition of 1% of Sb_2O_3 reduces the layer resistance by a power of ten, but with further additions the resistance increases.

The present investigations show that even much greater ranges of values of layer resistance are obtainable. For instance, the specific resistance at 20°C can be selected with any value between 0·0005 and 30 ohm-cm, while the standard resistance (which is approximately that of specimens 10 mm in diameter and 40 mm in

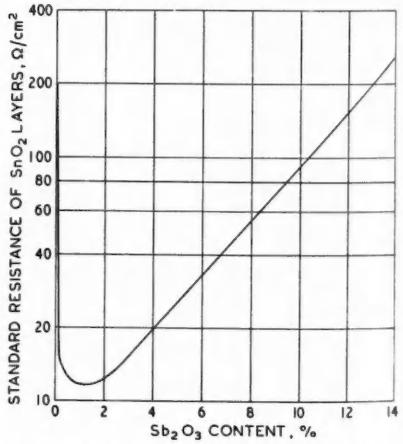


Fig. 1. Dependence of SnO_2 standard resistance on Sb_2O_3 content.

length) can be varied from about 5 to 300,000 ohms by altering the manufacturing conditions. Moreover, there is the possibility of increasing or reducing the resistance by several additional powers of ten by varying the distance between the terminal contacts and by having grooves cut in the resistive layer.

As regards the temperature coefficient α, some preliminary definitions are necessary. For metal conductors it is known that $\alpha = (dR/dT)/R$ is practically constant in the usual range of room temperatures. For conductors subjected to high temperatures, however, the resistance variation is exponential[3], in accordance with the relation

$$R = ae^{bT}$$

where a and b are constants for the material considered and T is the absolute temperature [°K].

For oxidic semiconductors, it has been observed by Meyer and Neldel[4,5] that there is a relation between b (which is an "energy constant" associated with the release of electrons) and the specific resistance ρ; in other words, with increasing ρ-values, b also increases. Now, between the value of b and the temperature coefficient α, the following relation exists[6]:—

$$\alpha = -b/T^2$$

i.e., α becomes increasingly negative for high values of b, and hence of ρ. This is known as Meyer's rule and has also been confirmed in the tests mentioned above.

However, the resistance/temperature curve of layer-type resistors is exponential only within a certain range. Resistors with positive or slightly negative α-values follow, like metals, a proportional relationship between R and T. The temperature curve becomes truly exponential only when α has an appreciable negative value, i.e., less than −0·6% per °C. For intermediate values of α, there is a transition range between linear and exponential temperature dependence.

Current/Voltage Characteristics

Static current/voltage characteristics were plotted, and it was found that the V/I curve is linear for low loads, i.e., at low temperatures; at increased loads, if the value of α is negative, there is a falling off in resistance, with a smaller voltage drop across the resistor than in the case of a constant resistance. Examples are shown in Fig. 2.

There is no reversal point of the voltage/current characteristic, as is generally the case for other semiconductors, because, as shown by Kanter[7], this occurs only if the temperature coefficient has an extremely large negative value (−1·3% per °C or even more).

Heating Time and Surface Temperature

The heating time, i.e., the time required by an oxide-layer resistor to reach constant temperature and a constant voltage drop, depends on various factors, such as shape, heat dissipation, and value of applied voltage. As a rule, up to 80% of the equilibrium temperature is reached in about 1 min; complete equilibrium is attained in 5 to 10 min.

Comparative tests were made with varnished and non-varnished resistors in still air and in a fan-induced draught. In still air, the temperature of the oxide layer was the same with and without the varnish, whereas the temperature of the varnish was 10 to 15% lower. It was found that, with the draught, heat dissipation was approximately doubled at the same working temperature (e.g., from 1·0 to 2·0 W/cm² at 250°C, for resistors 40 mm long and with an outside diameter of 30 mm).

Stability and Surface-Loading Capacity

As the conduction mechanism of oxide-layer resistors is similar to that of oxidic semiconductors, the question as to their stability can appropriately be answered by a comparison with the usual commercial thermistors. The latter generally consist of spinels or mixed oxides and are manufactured by sintering, the units thus obtained being a coarse-grained, porous mass of not quite uniform composition. Owing to their porosity, there is the risk that gases from the atmosphere may diffuse into thermistors and alter their electrical properties. As a result, these resistors are not absolutely constant and their temperature curve in a log-log graph is not absolutely linear. In contrast, oxide-layer resistors, which are free from pores and practically homogeneous, give a straight line in the log-log graph with a temperature coefficient of −0·6% per °C, and the results are fully reproducible after several heating and cooling cycles.

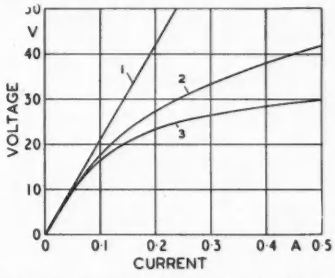


Fig. 2. Current/voltage characteristic of oxide-layer resistors for temperature coefficients α = 0 (curve 1), α = −0·37% per °C (curve 2), and α = −0·75% per °C (curve 3).

Continuous operation over periods of three months also showed only small deviations (from −0·38% to + 1·1%) from the initial resistance values of various samples. With unvarnished samples, there was an initial decrease in resistance of about 3%, owing to drying out caused by the flow of current, as in the case of carbon resistors[8]. However, drying is completed after 2 to 3 days. In dry air, the variation is less than ±1%. On the other hand, the resistance of varnished samples remains practically unaltered, even after fairly long storage.

When constancy is the main requirement, oxide-layer resistors should not be subjected to loadings greater than 0·15 to 0·2 W/cm², corresponding to a surface temperature of the order of 100°C. A few overloads to two or three times this value, however, will have no effect, but repeated overloads may cause changes in resistance of from 1 to 2%.

Ageing

Particularly interesting results were obtained in ageing tests, which were carried out at temperatures of from 400 to 1000°C. It was found that there is a fundamental difference between layer resistors with positive and slightly negative temperature coefficients on the one hand, and resistors with a pronounced negative temperature coefficient on the other hand. With the former, there is a more or less pronounced increase in resistance after heat treatment, and the temperature coefficient, even when originally positive, becomes negative. However, in the case of resistors with a pronounced negative temperature coefficient, heat treatment produces a decrease in resistance, together with flattening of the resistance/temperature curve. These changes were more marked at 900 or 1000°C than at the lower temperatures (400 to 600°C).

Resistors with High Wattage Ratings

The investigations showed that the stable operating range could be increased very considerably by using multi-layer elements, i.e., resistors having not one but several layers of different compositions deposited on the ceramic base. Multi-layer tube-type resistors of 50 to 60 cm in length and about 5 cm o.d. were fitted with terminal connections and subjected to intensive heating by direct passage of current for five consecutive 100-hr periods at 600, 700, 800, 900, and 1000°C. Fully reproducible results were obtained with different specimens, and the curves given in Fig. 3 show that comparatively little resistance variation occurs up to 800°C. The resistors withstood the 1000°C test without failure, in spite of the previous 400-hr heating.

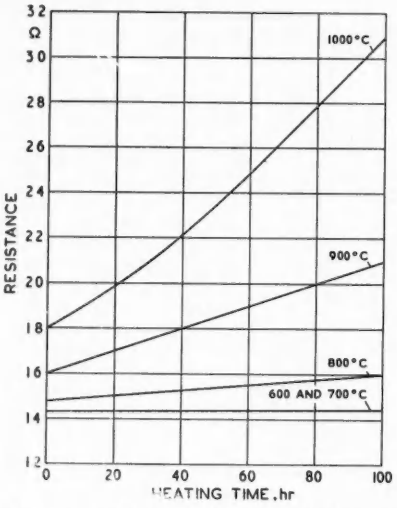


Fig. 3. Resistance of multiple-layer resistor tubes with direct passage of current, as a function of heating time, for various operating temperatures.

The cold resistance, determined from current and voltage measurements, was initially 12·5 ohms; after heating at 900°C it reached 35 ohms and then increased to about 100 ohms in the last 100 hours at 1000°C. Therefore, it appears that the initially slightly positive temperature coefficient became negative as a result of heating. Smaller resistance elements of this type, of about 5 cm in length and 1 cm o.d., behaved even more favourably under similar conditions. With heating periods of more than 2000 hr at 900 to 1000°C, the high-temperature resistance increased by 10 to 20%, whereas the cold resistance reached figures twice or even four times that of its initial value.

Possible Applications

The two main properties which make the use of oxide-layer resistors a matter of practical interest are (1) their negative temperature coefficient and (2) their stability at high temperatures.

Admittedly, resistances with a negative temperature coefficient have been known for a long time ; for instance, there are the thermistors, previously mentioned, which at room temperature have an α–value of —2 to —6% per °C, and also the carbon-layer resistances, for which α is situated between —0·15 and —0·02% per °C. However, what has been lacking hitherto has been the negative counterpart to the temperature coefficient of pure metals (+0·4 to +0·6% per °C). In electrical instruments, this positive temperature coefficient can be the cause of error in indication, owing to the change in resistance of the copper coil when subjected to temperature fluctuations. To compensate this error, various circuits are used[9]. The simplest solution would be to use a series-connected resistance with a negative temperature coefficient. Thermally sensitive resistors have been employed for this purpose but, because of their low degree of constancy and exponential temperature dependence, they provide compensation only within narrow temperature limits. Oxide-layer resistors with a temperature coefficient of —0·4% per °C, as compared with copper, which has a coefficient of +0·4% per °C exhibit, however, an approximately linear temperature characteristic, so that, with these in series, compensation is possible to a considerable extent.

In a test, the total measured value of resistance was 217·7 ohms at 22·6°C and 217·97 ohms at 46·6°C (the resistance of the oxide layer being 112·1 ohms and that of the copper coil 105·6 ohms, both at 20°C). In another temperature compensation test, the same oxide-layer resistor was connected to a platinum resistance thermometer, both of which had, at room temperature, approximately the same resistance, with equal and opposite temperature coefficients. In this case also, the sum of the resistances of the oxide layer and the platinum remained practically constant (219·86 ohms at 21·8°C and 219·73 ohms at 49·4°C), the temperature-dependent decrease in resistance of the platinum being slightly overcompensated by the semiconductor only at the lower end of the range.

The stability of multi-layer elements heated by direct passage of current indicates the possibility of their use as tubular heaters. At operating temperatures of 700 to 800°C, a service life of several thousand hours can be expected.

The maximum wattage rating for freely radiating tubes is about 10 W/cm². In furnaces, such tubes can still operate at 2 to 3 W/cm² when fitted into furnace walls. The intention is not so much to produce these tubes as a substitute for the usual domestic heater units, although this would be conceivable in the indicated temperature range, but to recommend that they be employed, for instance, for the heating of fairly large areas or for other special applications.

References

(1) Corning Glass Works : " Elektr scher Widerstand und Verfahren zu seiner Herstellung." German Pat. No. 908,882.

(2) R. Glang : " Untersuchung von Fehlordnungszuständen im Zinndioxyd " ; Diss. T. H. Darmstadt, 1955.

(3) E. Justi : " Leitfähigkeit und Leitungsmechanismus fester Stoffe " ; Vandenhoeck & Ruprecht, Göttingen, 1948, pp. 179 *et seq.*

(4) W. Meyer : " Über die Elektrizitätsleitung anorganischer Stoffe mit Elektronenfähigkeit." *Z. Phys.*, Vol. 85, 1933, pp. 278–293.

(5) W. Meyer and H. Neldel : " Über die Beziehungen zwischen der Energiekonstanten ε und der Mengenkonstanten α in der Leitwerts-Temperaturformel bei oxydischen Halbleitern." *Phys. Z.*, Vol. 38, 1937, pp. 1014–1019.

(6) H. Kanter : " Temperaturabhängige Widerstände 1 " ; *Arch. techn. Messen*, July, 1955, Z 119/3.

(7) H. Kanter : ' Temperaturabhängige Widerstände II " ; *Arch. techn. Messen*, August, 1955, Z 119/4.

(8) A. Schulze : " Metallische Werkstoffe der Elektrotechnik " ; Metall-Verlag, Berlin, 1950, p. 215.

(9) C. Reher : " Kompensation des Temperaturfehlers von Gleichstrominstrumenten " ; Part 2 ; *Arch. techn. Messen*, April, 1939, J 023/2.

Designing Machine Tools for Automatic Control

By C. B. SUNG. (From a paper presented at the *ASME Design Engineering Conference*, New York, May 22, 1957, 40 pages, 13 illustrations.)

THE computer and feedback control techniques developed during the past decade have been largely responsible for progress in converting from mechanization to automatic control. Machines and equipment are no longer mere labour-saving devices or energy converters, but are capable of self-regulation by means of internal systems. Many machines even have a brain-type mechanism which is capable of interpreting brief instructions in coded form. Indeed, these machines and equipment should be more appropriately regarded as systems, since most of the elements and components involved are interrelated and interdependent. Consequently, the systems concept must prevail and integrated design becomes a necessity.

Perhaps one of the most interesting developments to illustrate the state of automatic control is a numerically controlled machine-tool system. A typical system of this type, developed by the Research Laboratories Division of the Bendix Aviation Corporation, U.S.A., manufactures finished parts directly from numerical data representing working-drawing information. It consists of two sub-systems, i.e., a tape preparation system and a tape-controlled machine-tool system. The tape preparation system produces control tapes from working drawings, the control tape being applied to the machine control unit, which interprets the perforations on the tape and commands the machine to make the desired part. The control tape may be stored indefinitely and re-used.

The process tape is made simply by typing a duplicate of the process card on a tape perforator, which is equipped with a regular typewriter keyboard. The process tape is then fed into the computer, which calculates the feed-rate information, computes the cutter-centre offset, generates the intermediate points, and finally punches the control tape, which contains a coded representation of incremental tool movement from one intermediate point to the next in the desired sequence. Since, in this particular system, the machine control unit performs linear interpolation between the intermediate points, the computer is required to calculate these points along the curved path, so that the finished part is within the specified accuracy or surface finish.

The tape-controlled machine-tool system is composed of two major parts, i.e., a machine control unit and a machine. The machine control unit contains the intelligence part of the system, while the machine accommodates the power part and sensing elements. Fig. 1 is a simplified functional block diagram of the tape-controlled machine system for simultaneously controlling the motion of three axes. The control tape is intermittently read by the machine control unit just one step prior to the respective machining operation. A section of the tape, usually less than 2 in. long, representing the incremental tool motion between two intermediate points, is fed through the tape reader only when required by the machine control unit. The information is then stored in a buffer storage, so that the eventual input command to the machine is always of a continuous nature, unless the control tape commands otherwise. The interpolator linearly interpolates the information and issues commands in the form of electrical pulses simultaneously to the three axes at the respective specified rates. In a typical case, each pulse is chosen to represent 0·0002 in. of travel. Also, each axis of motion has geared to it a " quantizer ", which is a rotary digital instrument sensitive only to displacement and insensitive to speed, and which produces a feedback pulse for each 0·0002 in. of travel.

For each axis, there is an error register. This unit receives command pulses from the interpolator, and feedback pulses from the quantizer, continuously comparing these two signals and transmitting the difference, known as the error signal, to the servo-amplifier. Through the servo-amplifier and the related circuitry, the error signal is converted into analogue form and amplified. This amplified signal actuates the hydraulic drive, which, in turn, meters and transmits power from a hydraulic supply to the respective slide against the various types of load disturbances, including inertia, friction, and cutting forces. Since a portion of the system, as shown in Fig. 1, employs the concept of feedback control, it is known as a feedback-control, servo-, or closed-loop system. These terms are used synonymously in this discussion.

Recent technological advances have already proved that an automatic machine-tool system is no longer a laboratory model, but rather a practical and reliable manufacturing tool. Thus, for example, one particular tape-controlled three-dimensional cam machine has been in successful operation for a period of over 12,000 hr.

The industry shows a rapid trend towards more automatic control. This trend, however, could definitely be hindered by the improper application of automatic control techniques in both economical and technical senses. It should be recognized that certain types of machining operations are more economically suitable for automatic control than others. At present, the application of automatic control to these other types will result only in marginal improvements, and the justification of such an application is largely governed by the cost of control equipment. There are still other types of operations from which an economical yield by means of automatic control cannot be anticipated for some time. When applying automatic control to a given type of machining operation, the choice between the adaptation of an existing machine, the extensive modification of an existing machine, and the designing of a new machine is again dictated by economy.

The need for automatic control may not always be obvious if the viewpoint is focused on machine tools of existing form, with automatic control merely as an added improvement. Perhaps another way of visualizing the benefit of automatic control is by examining how certain parts could be better produced. An even more radical method of evaluating the application of automatic control is to ascertain how some machines and equipment can be better designed and more economically constructed. In this way, the meaning of integrated design is truly achieved in its broadest sense.

INTEGRATED DESIGN

In the design of machine tools for automatic control, many challenging problems are presented. A designer must often decide whether it is just a matter of adding control devices to an existing machine tool or whether there are some basic design considerations involved. Indeed, it is highly conceivable and feasible that many existing machine tools may be adapted for automatic control merely by adding the appropriate machine control units, servo-drives, and feedback instruments.

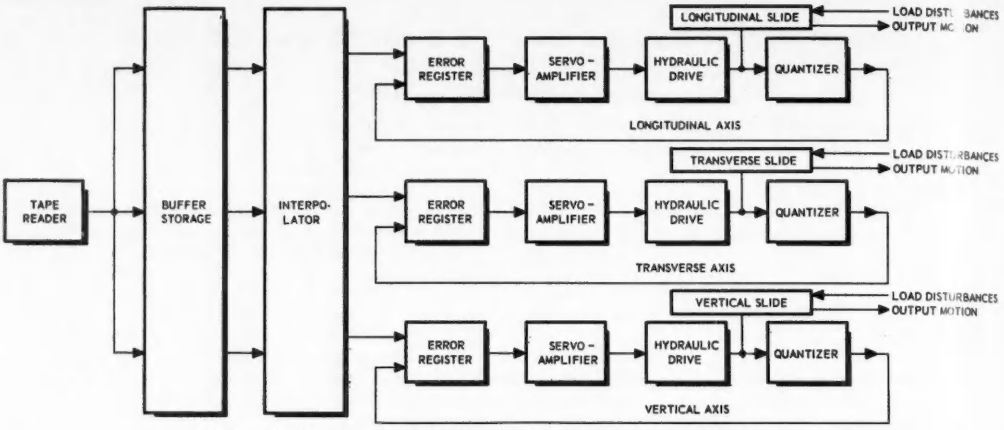


Fig. 1. Simplified functional block diagram of a tape-controlled machine-tool system.

At the turning point between mechanization and automatic control, the need for integrated design becomes even more important. From the functional viewpoint, there are apparently two aspects to consider in integrated design, i.e., the manual control aspect and the automatic control aspect.

Manual Control Aspect :—

In handling small-lot production and also in the manufacture of prototype parts, the initial set-up of workpiece and cutter still relies on human effort. Nevertheless, by utilizing or sharing some of the inherent features of control devices, a substantial saving in both equipment and effort can be realized. This approach can be illustrated by the use of servo-mechanisms for sensitive manual adjustment and the use of feedback instrumentation for accurate measurement. The saving in down-time for set-up is especially important because, with automatic control, the equipment becomes more valuable, both with regard to its higher initial cost and higher productivity.

Manual control becomes even more important during the automatic control mode. It is not realistic to consider that human attention is not required during the tape-controlled phase of the operation. It is true, however, that the amount of human attention may be drastically reduced. During the automatic control mode, the function of the operator is to supervise operation of the machine and not to exercise close control. In order to be able to command temporary changes in operation to meet unexpected conditions, there should be sufficient flexibility designed into the system. For instance, if the material or design of the cutter is different from that of the original specification, the operator should be able to make a simple adjustment to alter the feed rates so as to meet metal-removing requirements without upsetting the continuous automatic operation. If it is required to make a check on the cutter and/or the part, he should be able, without difficulty, to stop the operation, withdraw the cutter, make the check, and restart the operation. Thus, a definite requirement exists for manual override of the automatic control, and such a phase must be considered in the integrated design.

Automatic Control Aspect :—

Since, during the automatic control mode, neither detail command nor close control is handled by the operator, the dynamic response of the machine tool to any given command from the tape is no longer limited by human response. To design a machine tool with adequate dynamic response, so as to take full advantage of the benefits of automatic control, designers must follow the approach of integrated design or what is sometimes designated "systems engineering". The essence of this approach may be stated as consisting of three phases, i.e., the establishing of system requirements, servo-systems engineering, and finalization of overall design.

The establishing of overall system requirements, type of automatic control, and machine configuration includes :

(1) Formulating such performance requirements of the machine tool as types, sizes, and materials of the parts to be machined ; machining processes involved ; nature of the information required for machining ; stock-removal capacity ; accuracy and surface finish of the finished part ; and required control features and auxiliary functions.

(2) Selecting the type of automatic control system which will result in a maximum economic yield when integrated with the machine.

(3) Determining the capacity or power of the work-holding and cutter-holding devices.

(4) Establishing optimum machine configuration and the desirable stiffness under various orientations.

The performance of servo-systems and the obtaining of preliminary layouts of servo-equipment and related elements necessitate :—

(1) Reducing performance requirements to a set of specifications covering both steady-state and dynamic operation of various moving axes under servo-control, e.g., range of travel ; estimated weight of moving members ; range of feed rates and rapid traverse rate ; type of input command ; nature and magnitude of load disturbances ; resolution of feedback instruments ; static accuracy ; amount of permissible hunting, if any ; permissible steady-state error ; and transient error under various cutting loads.

(2) Expressing specifications in terms of a set of lower-bound design criteria for all the components affecting servo-performance, such as power delivered or transmitted ; speed range ; undamped natural frequency ; friction characteristics ; inertia ; and amount of permissible back-

lash of the drive units, drive mechanisms, feedback mechanisms, feedback instruments, and machine members.

(3) Choosing qualified components and making realistic alternative layouts to fulfil dynamic specifications, as well as other considerations such as reliability, maintenance, capital investment, and cost of operation.

(4) Performing both open-loop and closed-loop dynamic analysis of alternative layouts.

(5) Comparing the results of analyses of various systems, and determining whether system performance will remain acceptable with reasonable variation of critical parameters.

(6) Making mock-up tests or simulation studies, if necessary, to confirm some of the assumptions.

Finalizing of overall specifications, layouts, and detailed design entails :—

(1) Choosing a layout with one of the best overall ratings and making the necessary compromise on original specifications.

(2) Making a set of complete layouts and design criteria by integrating all finalized specifications and stating allowable variations of critical parameters.

(3) Proceeding with detailed design accordingly.

(4) Formulating a set of simple tests, as an aid to assembly work, for checking friction characteristics, stiffness, amount of backlash, amount of preload in bearings, and alignment of the relatively critical components and assemblies.

Machine-Tool Servo-Mechanisms

A functional block diagram of a typical machine-tool servo-system for automatic control is shown in Fig. 2. This essentially consists of the servo-portion of the overall system shown in Fig. 1 in a more generalized form. The intelligence part, usually handled by electric and/or electronic equipment, may be either digital or analogue. The servo-actuator, which is the centre of the servo-system, converts the amplified error signal into motion and may be an electric motor or a fluid actuator. The drive mechanism consists of a gear-train, a rack-and-pinion arrangement, a lead-screw, or some combination of such devices. There may be no need to employ a drive mechanism, if rectilinear motion is directly controlled by a rectilinear actuator, and rotary motion directly controlled by a rotary motor. The controlled machine member may be the work spindle, the cutter spindle, the machine slide carrying the work or cutter, the intermediate machine slide, or the lead-screw driving the machine slide. The feedback instrument may be either rectilinear or rotary, and gearing may be used between the instrument and the controlled machine member.

Four types of controls are required for machine-tool applications, i.e., (1) position control, such as that used in jig-boring and drilling operations ; (2) rate control, such as that used in variable-speed spindle control ; (3) position and rate control, such as those used in turning operations ; and (4) continuous contouring or instantaneous position control, such as those used in milling operations.

A position-control servo may be effectively used as a rate-control servo, but generally the reverse is not practical. From these four different types of control, it becomes obvious that the quality of servo-mechanism needed is not only governed by the capacity, productivity, and precision requirements of the machine tool, but also more fundamentally by the type of control involved. For example, type (1) requires only static position accuracy, while type (4) requires both static and dynamic position accuracy and sometimes feed-rate regulation. For the same class of machines, type (4) would undoubtedly need a higher-quality servo than type (1).

Characteristics of Servo-Actuators :—

Before the meaning of the quality of a servo-mechanism can be discussed, it is advisable initially to consider the characteristics of a servo-actuator. For the type of servo-actuator generally used for machine-tool control, a given actuating signal produces a certain constant rate of change of position. There are servo-actuators which, on receiving a given signal, produce a certain position or acceleration output rather than velocity. In this discussion, only the type of servo-actuator with a velocity output is considered. This type is perhaps most frequently utilized and is the most suitable for both position control and continuous contouring control.

One of the primary reasons in using servo-mechanisms for machine-tool control is to achieve accurate position control without the requirement for predicting the exact magnitude and nature of load disturbances,

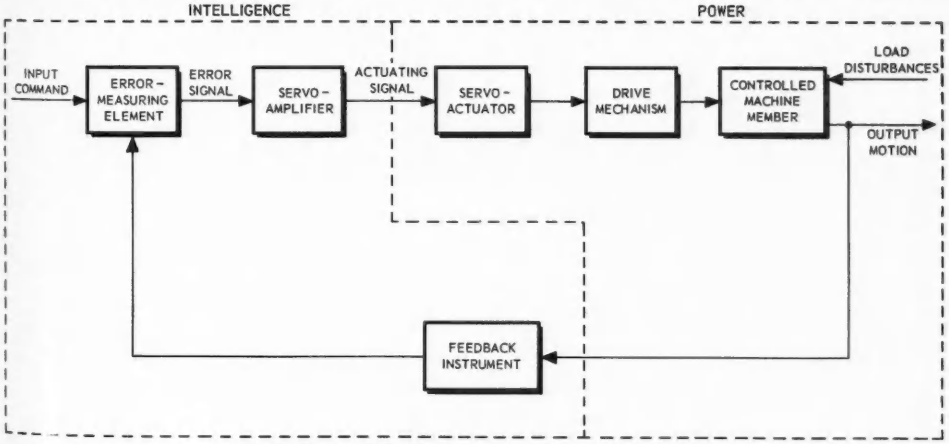


Fig. 2. **Functional block diagram of a machine-tool servo-system.**

provided that they vary within the bounds for which the servo-mechanism is constructed. Therefore, the characteristics of the servo-actuator with respect to load-handling capability is of vital importance. In general, the static characteristics of a servo-actuator can be expressed in terms of two factors, i.e., gain and load sensitivity. For a given constant load on the actuator, the gain is defined as the velocity output of the servo-actuator for each incremental unit of actuating signal. For a given constant velocity of the actuator, load sensitivity is defined as the force or torque output of the servo-actuator for each incremental unit of actuating signal. For servo-actuators with linear characteristics, gain and load sensitivity remain the same at various velocity and load levels. In other respects, the servo-actuator is known to have non-linear characteristics.

Response of Servo-Actuators :—

The quality or performance of a machine-tool servo-actuator is actually a measurement of its response and stiffness under both steady and dynamic conditions. The response of the actuator is defined as its ability to follow the input command. In order to illustrate the meaning of the principal governing factors, it is assumed that the actuator is under a constant load disturbance. The loop gain k_v[sec^{-1}] and band-width ω_b[rad/sec] may be regarded as two major factors governing servo-response. The loop gain for the servo has the same meaning as the gain of the servo-actuator. Referring to Fig. 2, it is the ratio between the output steady-state velocity of the controlled machine member and the amount of error signal required to produce such a velocity. For this reason k_v is also known as the velocity-error constant.

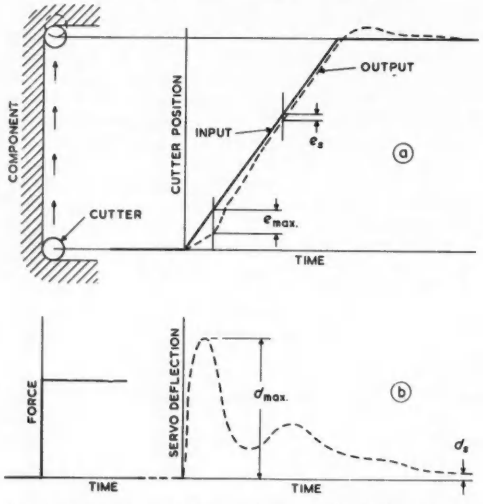


Fig. 3. Measurement of servo performance, illustrating (a) servo response to a severe input, and (b) servo deflection due to an impact load.

Prior to defining the term band-width, the technique of frequency response may be introduced. In analysing, synthesizing, and testing various systems with regard to their dynamic performance, a convenient technique (frequency response) is often used. Essentially, by applying a sinusoidal input of a certain frequency to a linear system, the output is also a sinusoidal motion of the same frequency. The dynamic properties of the system can be better understood by studying the amplitude ratio and phase shift between the output and input at various frequencies*. The frequency at which the amplitude ratio begins to deviate appreciably from unity or at which the phase shift becomes 90 deg. may often be used as a qualitative measurement of the dynamic properties of both open-loop and closed-loop systems. For most systems, the frequency at a 90-deg. phase shift may be regarded as the undamped natural frequency for the lowest mode of motion. In this discussion, the band-width ω_b is arbitrarily defined as the frequency for the -3 db point (or approximately 0·7 amplitude ratio) or 90-deg. phase shift, whichever is the first to occur. Although this type of qualitative measurement is basically for linear systems, if properly applied and interpreted, it may also be useful in dealing with non-linear systems.

For machine-tool servos, one of the most severe input commands is to order an inert machine member to reach full feed rate instantaneously and then to stop instantaneously. Fig. 3a shows the response of a typical machine-tool servo to such an input and indicates the lag between the output and input. According to the definition of k_v, the steady-state error e_s can be obtained as

$$e_s = v/k_v \text{ [in.]} \quad .. \quad .. \quad .. \quad (1)$$

where v = velocity input [ips.].

Also, the maximum transient error e_{max} may be estimated from the following approximation :—

$$e_{max} = v/\omega_b \text{ [in.]} \quad .. \quad .. \quad .. \quad (2)$$

If k_v and ω_b of a linear servo have values of 1000 and 80 respectively, with an input command moving the machine member from zero to 30 ipm, the steady-state and maximum transient errors can be estimated as 0·0005 and 0·0063 in. respectively. Eq. (2) is not an accurate approximation, and usually the result of such an approximation may deviate from the exact value by as much as 30%.

It is apparent that the higher are the values of k_v and ω_b, the better is the response of the servo. For a given design, however, there are limits to how high these values can be before the system becomes or tends to become unstable. The band-width of the servo is an indication of the resulting dynamic response of the amplifier, the dynamic properties of the actuator, and the inertia, spring, and friction effects of all the elements directly affecting the loop. In general, the component with the lowest band-width in the loop determines the upper limit on the servo band-width. It is also possible that the limit is governed by some elements outside the loop. Proper design of compensating networks in the servo-amplifier may considerably improve the value of k_v, but they should not be relied upon to make appreciable improvements on ω_b. Without the use of a compensating network, the ratio k_v/ω_b for a relatively stable machine-tool servo is usually in the range between 0·7 and 2. By means of a compensating network, the value of k_v may be raised by a factor of 10 or 20, or even higher, without causing an appreciable reduction in ω_b. Too high an increase in k_v, however, often lowers the dynamic response of the servo, if a given margin of stability is to be maintained.

Stiffness of Servos

The values of k_v and ω_b have a similar direct influence on the stiffness of the servo. Fig. 3b illustrates the

(*Continued on page 398*)

* H. CHESTNUT and R. W. MAYER : "Servomechanisms and Regulating Systems Design (Vol. I)" ; Wiley & Sons, Inc., N.Y., 1951.

U.S.A.

Microsectioning as a Metallographic Technique for Semiconductor Devices

By J. S. Hanson. (From *IBM Journal of Research and Development*, Vol. 1, No. 3, July 1957, pp. 279–288, 11 illustrations.)

In this article details are given of a microsectioning technique which permits metallographic sectioning of fragile semiconductor devices, without the difficulties and possible damage to specimens associated with conventional techniques.

Specimens of semiconductors selected for microsectioning may fall into a number of categories, including those with abnormal physical or electrical characteristics. In the case of a *p-n-p* alloy-junction transistor, for example, containing very thin sections of hard, brittle germanium adjacent to soft indium, specimens cannot be embedded or potted for sectioning by conventional pressure-moulding techniques, because of the possibility of fracturing the germanium. Furthermore, they cannot be polished by resilient fabrics charged with abrasives, because of rounding off of the edges of the germanium.

This paper describes a metallographic sectioning technique which overcomes these difficulties and which permits preparation of specimens in a reasonable amount of time, utilizing miniature containers having a diameter more compatible with the physical size of the specimens.

The first step in the procedure is a careful inspection of the specimen under both metallurgical and stereomicroscopes for geometry, surface data, and external defects pertaining to a particular study. If the specimen is one of a kind, or one which exhibits unusual electrical characteristics, these observations are of special importance in choosing the position of the sectioning plane. This choice may not always yield the most data but, if a number of specimens is available from the same lot, various sectioning possibilities may be distributed among a sufficient number of samples for the greatest yield of information.

Selection of Sectioning Planes

Selection of the sectioning plane is the next step. As an example, consider the alloy-junction transistor with abnormal recrystallization shown in section in Fig. 1,

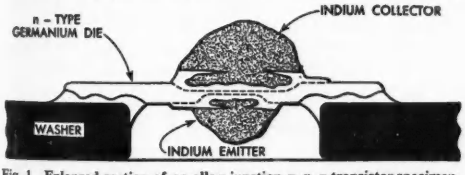


Fig. 1. Enlarged section of an alloy-junction *p-n-p* transistor specimen, showing abnormal recrystallization.

and assume that germanium crystallographic orientation error and collector eccentricities with respect to the washer hole are major considerations, and that it is desired to study their effects on alloying and recrystallization behaviour. One plane, e.g., that shown in Fig. 2a, is chosen to observe alloying behaviour on the basis of maximum eccentricity between the collector and the washer hole, with some crystallographic orientation error present, this error in the plane of the section being the angle θ between the surface of the germanium die and the dotted lines denoting the geometrically flat and parallel alloy junctions.

Another sectioning plane is also selected, as shown in Fig. 2b, to observe maximum crystallographic orientation error of the germanium and its effect on alloying behaviour, with almost maximum eccentricity between the collector and the washer hole. It is not possible to determine this particular sectioning plane on every specimen, because some transistors lack the necessary externally visible collector-emitter formations and germanium etch-pit geometry. A third plane (Fig. 2c), approximately 90 deg. from the plane in Fig. 2b, reveals alloying behaviour with negligible crystallographic orientation error.

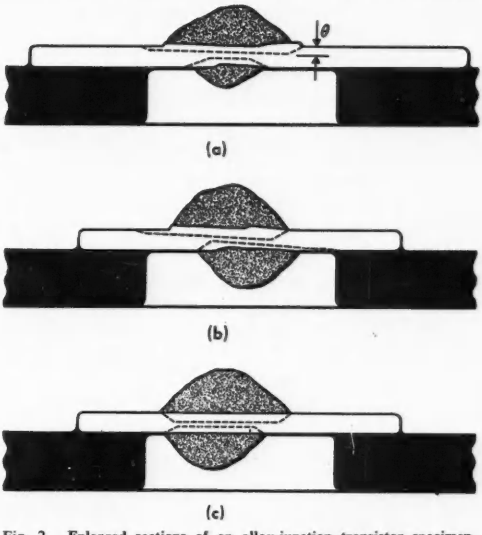


Fig. 2. Enlarged sections of an alloy-junction transistor specimen, illustrating various sectioning-plane possibilities.

Many specimens are sectioned only for a determination of the junction spacing or for a study of some large externally visible defect or an unusual alloying behaviour. It becomes a simple matter, then, to lap down and inspect alternately, until the sectioning plane appears to pass roughly through the centre of the configuration being studied. If the configuration is only 0·001 in. or so in size, however, a more precise location of the sectioning plane is required, and it is then necessary to note its position with respect to a reference point on the periphery of the washer. Subsequent micrometer caliper measurements from a datum plane tangent to the washer at this reference point determine when the sectioning plane is reached during lapping and polishing operations.

Mounting of Specimens

Since the specimens are only about $\frac{1}{8}$ in. o.d., it is convenient to use small transistor encapsulation cans (0·215 in. o.d. × 0·3 in. high) as mounting containers. This saves a great deal of the time and labour required to lap and polish samples mounted in conventional containers of 1 in. or more in diameter.

The mounting material in which the specimen is potted should have the following properties :—

(a) Low viscosity to permit flow into microscopic crevices in the specimen without trapping air bubbles.
(b) Negligible shrinkage during hardening.
(c) Sufficient hardness and toughness for approximately the same rate of wear as the specimen during lapping and polishing.
(d) Good adherence to surfaces, to preserve specimen edge details.
(e) Negligible tendency for the surface to load up with grit particles during lapping and polishing.
(f) Negligible attack by strong acid mixtures.

In the course of a search for better potting materials, it was noted that a particular stopping-off lacquer commonly used in the electroplating industry for selective masking had desirable qualities of hardness, toughness, and tenacity, when used as a coating material for specimens. When diluted with an equal amount of lacquer solvent, it effectively wets metal surfaces and flows into narrow crevices without trapping air bubbles. The coating thickness can be built up by successive dippings until corner radii are large enough to permit the use of an otherwise too viscous epoxy resin compound.

If dipping with stopping-off lacquer is impracticable for any reason, prefilling small recesses in the specimen with a globule of epoxy resin on the point of a sharp needle, or drawing a momentary vacuum on specimens precoated with resin, just before potting, may perhaps be more convenient. Potted specimens are allowed to harden overnight at room temperature, in order to avoid thermal distortion and pulling away of the potting material from the specimen. Greater care is used in potting specimens requiring lapping and polishing to within $\pm$ 0·0001 in. of the desired sectioning plane, since the reference plane must be normal to the axis of the mounting container.

Mechanical Rough-Lapping

If there are many specimens to be microsectioned, it is more practicable to resort to a mechanized rough-lapping operation to secure uniformly good quality than to attempt to do it by hand. A machine, called the microsectioner, has been developed for this purpose and consists essentially of a horizontal motor-driven turntable surfaced with abrasive paper, on which rides a rapidly oscillating arm carrying the specimen, which is mounted in an accurately machined brass sleeve.

Specimens requiring lapping and polishing to within $\pm$ 0·0001 in. of the desired sectioning plane are first lapped on the microsectioner until a previously designated reference point lies in the lapping plane. A micrometer caliper measurement of the initial overall length of the specimen and sleeve is then noted, and lapping is continued until the final measurement is reached, the difference between these measurements being the distance from the reference point to the desired sectioning plane, with an allowance for polishing.

Polishing Techniques

In most semiconductor specimens, the rough-lapped surface is characterized by hard, brittle areas adjoining very soft areas. The surface must be polished to a high degree of perfection in both flatness and optical reflectivity before it can be observed under a metallurgical microscope for the study of cross-sectional configurations.

If resilient polishing fabrics or papers charged with abrasive are used, as in conventional metallographic techniques, there is a tendency for softer areas to wear down faster and the edges of the hard material to round off, thereby obscuring these effects in the microscope. An alternative polishing technique with negligible rounding-off action utilizes a sheet of smoothly stoned hard-surfaced vellum or tracing paper dry-charged with 0·3μ aluminium oxide polishing powder, and a specimen holder, 1 in. in diameter, to keep the specimen surface parallel to the polishing plane.

Alternate polishing and inspection are continued until the desired sectioning plane is reached or until the surface is of the desired quality. Specimens requiring extreme accuracy in sectioning-plane position are also checked with micrometer calipers during polishing, to determine when the sectioning plane is within 0·0001 in. of the desired position. Specimens containing fragile recrystallization formations are polished very carefully with a straight-line motion in a direction parallel to these configurations, to avoid damage.

Whenever the vellum becomes darkened it is cleaned with trichlorethylene or some other suitably volatile solvent and is recharged with polishing abrasive.

After polishing is completed, significant surface configurations are noted and photographed, since they will be partially obliterated by a subsequent junction-etching treatment. The specimens are left undisturbed in the sleeves until all lapping, polishing, and preliminary microscopy are completed, after which the specimens are removed for etching.

Junction-Etching

The purpose of etching is to create line patterns which indicate such factors as alloy- or diffused-junction positions within the semiconductor material, alloying behaviour during processing, crystallographic misorientation, processing temperatures, upper limit of high-frequency response, and interelectrode capacitance.

The lapped and polished semiconductor surface is attacked by the etching solution at a rate depending on impurity types and concentrations, crystallographic orientation, residual stresses, the severity of lapping and polishing operations, etc. If a number of sample specimens made from material of the same origin is sectioned with reasonable care, impurity content then becomes the predominant factor governing etch rate, and the optimum etching time for best etch-line definition is easily determined. Accordingly, one-off specimens are given several very short etchings and inspections to avoid over-etching and loss of etch-line definition.

The etching solution most commonly used consists of 4 parts by volume of HNO_3 (70%), 4 parts HF (48%), and 1 part distilled H_2O. Another solution sometimes used consists of 2 parts HNO_3, 1 part HF, 1 part concentrated H_2SO_4, and 1 or 2 parts distilled H_2O, depending on the desired etching time. The specimen is held under a fine stream of the etching solution for the appropriate etching time (usually 1½ or 2 sec), rinsed and dried, and inspected for etch-line definition. Care must be taken to avoid over-etching; otherwise, the specimen must be repolished and etching repeated.

Microscopy and Photography

In this investigation, use was made of a metallurgical microscope, with a vertical-beam illuminator, an ×8 objective, and binocular eyepieces, and fitted with a special micrometer stage with a 0·1 × 0·1 in. movement, reading to 0·00001 in. on the verniers. One ×20 wide-field eyepiece contains a 5 × 5 square-net reticle, through which the specimen is photographed by means of a 35-mm eyepiece-camera, while the other eyepiece contains a

graduated cross-scale reticle for maintaining the image position and focus of the specimen.

Measurement of such specimen configurations as junction separation, and base and recrystallization region thicknesses are customarily made to the nearest 0·00001 in. on the micrometer stage. Other specimen dimensions of minor importance may be noted in terms of reticle cross-scale readings.

Interpretation of Data

The great value of microsectioning lies in the skill with which photomicrographs are analysed and evaluated, and in the effectiveness of recommended changes to correct abnormalities observed in sectioned specimens.

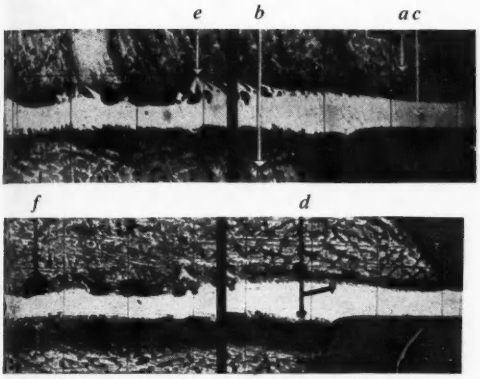


Fig. 3. **Cross-section of part of an *n-p-n* transistor with [100] oriented germanium, showing abnormal recrystallization and non-planar *n-p* boundaries.**

A large number of photomicrographs has been produced, and Figs. 3, 4, and 5 illustrate the manner in which an analysis is made. In each case *A* is a view of an as-polished section, and *B* the junction-etched section. The superimposed reticle squares are approximately 0·0047 in. in width. In all cases, a series of overlapping pictures was made, to form continuous panoramic photographs.

Fig. 3 shows part of an early version of an *n-p-n* transistor consisting of lead-antimony dots (*a*) and (*b*) alloyed on the [100] faces of a thin germanium die (*c*). This crystallographic orientation leads to an unstable alloying and recrystallization behaviour which is difficult to control, the result being non-planar *n-p* boundaries (*d*) and complex [111] plane configurations (*e*) between the recrystallized germanium and the dot material. Recrystallization failure and possibly poor voltage breakdown characteristics are indicated by the dark areas (*f*) under the emitter and collector dots.

The geometry of another *n-p-n* transistor was greatly improved by use of [111] oriented germanium, as shown in Fig. 4. In the as-polished view *A*, the germanium underneath the dots had recrystallized to practically its original thickness at (*a*). This transistor had been given a clean-up etch to reduce back-current leakage, so that the germanium outside the dots at (*b*) is only 60% of its original thickness, and considerable undercutting around the dot peripheries has reduced the germanium thickness to a fragile 20 or 30% of the original at (*c*) and (*d*). The bond between the germanium and the washer at (*e*) and (*f*) had numerous pits and blowholes. These are objectionable, because contaminants lodged therein during clean-up etching are not only difficult to remove, but migrate from these crevices at some period after the transistor has been encapsulated, destroying its electrical characteristics.

The junction-etched specimen (*B* in Fig. 4) shows the more desirable geometrically flat and parallel alloy junctions produced by the stable [111] recrystallization plane. Alloy penetration depth (and hence junction spacing) are more easily and precisely controlled by adjustment of the firing temperature, and such junction configurations provide better high-frequency response without sacrificing voltage breakdown limits between emitter and collector. The 1·5-deg. crystallographic misorientation of this specimen contributed to the " troughing " effect seen under the periphery of the collector dot at (*g*). This configuration produces deep, narrow crevices during clean-up etching which are difficult to clean out. Poor dot concentricities also contributed to unsatisfactory alloying and electrical characteristics.

The *p-n-p* transistor in view *A* in Fig. 5 shows an undesirable laminar recrystallization behaviour within the indium collector dot at (*a*). Since this configuration was extremely fragile, straight-line lapping and polishing, only were employed. Polishing was held to a minimum, and overall specimen section quality was partially sacrificed to avoid damaging the 0·0002-in. layer of recrystallized germanium within the indium collector dot. Measurements made on the junction-etched specimen in view *B* showed the alloying or wetting diameter of the collector to be 0·0230 in., and the recrystallization dia-

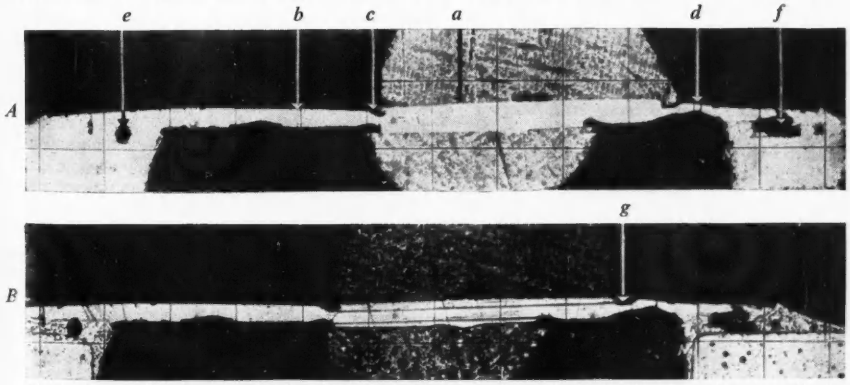


Fig. 4. **Cross-section of an *n-p-n* transistor, showing parallel-plane *n-p* boundaries produced by more stable recrystallization of [111] oriented germanium.**

meter to be 0·0256 in. Since no clean-up etching had been done, it is apparent that an initial recrystallization in a direction normal to the [111] face of the germanium die had taken place around the collector periphery at (*b*) and (*c*), before laminar recrystallization in easier directions parallel to the [111] face had begun. The upper surface of this lamination is actually 0·0008 in. above the original surface of the germanium die.

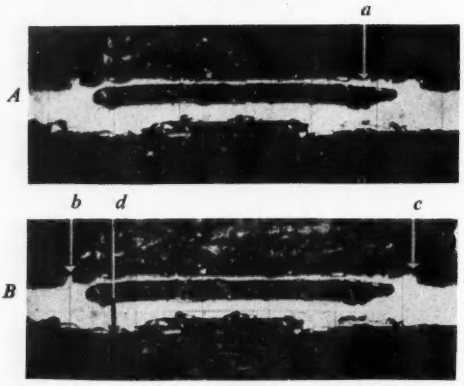


Fig. 5. Cross-section of part of a *p-n-p* transistor, showing severe laminar recrystallization and emitter retraction.

Measurements made on the emitter dot of view *B* in Fig. 5 showed that dot retraction had occurred during recrystallization. The alloying diameter was 0·0120 in., the recrystallization diameter was 0·0190 in., and the final diameter was 0·0160 in., indicating that the dot had retracted 0·003 in. at (*d*). Evidence of laminar recrystallization within the emitter dot, 0·0003 in. above the die surface, is visible, although efforts to preserve the formation were unsuccessful. The 0·00011-in. junction spacing was one of the closest ever observed in sectioned specimens. Bond quality was satisfactory in the sectioning plane, although three blowholes were observed in the bond fillet before the specimen was potted. Crystallographic misorientation was 0·35 deg., and some collector eccentricity was noted.

In general, since *p-n-p* transistors with laminar recrystallization exhibited increasing back-current leakage as clean-up etching progressed, the units eventually had to be discarded. Analysis of a typical laminar recrystallization serves to explain this behaviour and shows why such recrystallization is objectionable. In the first place, any extraneous recrystallization of germanium tends to reduce the total amount that would have otherwise recrystallized on the parent material of the die, so that an undesirable reduction in the thickness of the recrystallized *p*-region occurs. In the second place, a greater reduction occurs in more critical areas immediately under the periphery of the dot, by reason of the shielding effect of the laminar formation just above. The longer the clean-np etch is allowed to attack this periphery, the deeper and narrower the crevice becomes, and the greater the number of very thin recrystallized regions reached by the etchant under the dot periphery ; hence, an increase in back-current leakage due to cleaning is inevitable.

In *n-p-n* transistors having dot material inclusions and peripheral trough effects (both contributing seriously to reduction in thickness of the recrystallized *n*-type region), deep, narrow clean-up etch crevices were almost always formed.

Conclusions and Recommendations

On the basis of the foregoing observations and the photomicrographic analyses made, the following recommendations have been formulated :—

(1) A tolerance of ± 0·1 deg. on the crystallographic orientation of germanium dies should be adhered to.

(2) Firing jigs should be reworked to secure improved accuracy in the centering collector and emitter dots, with respect to each other and to the hole in the washer.

(3) Firing-temperature cycles should be revised, both in heating and cooling, to obtain better alloying and recrystallization behaviour.

(4) The necessary changes in initial surface-contact conditions between the germanium die and the washer should be made, in order to secure satisfactory bond-filler radii and freedom from blowholes and crevices.

With appropriate minor variations, microsectioning can be applied to almost any sub-miniature item. This technique permits the preparation of up to a dozen specimens per machine per day and is considerably more rapid than conventional metallographic techniques. Furthermore, use of the microsectioner need not be limited to one specimen at a time, nor only to rough lapping.

Designing Machine Tools for Automatic Control

(*Continued from page 394*)

deflection of a typical servo in response to an impact force or a step change in load. The servo is otherwise under a steady-state condition. The steady-state deflection d_s and the maximum transient deflection d_{max} may respectively be estimated from :—

$$d_s = f/(\lambda k_v) \text{ [in.]} \quad .. \quad .. \quad .. \quad (3)$$

$$d_{max} = f/(\lambda \omega_b) \text{ [in.]} \quad .. \quad .. \quad .. \quad (4)$$

where f = magnitude of the step change of load at the point where the deflection is measured [lb], and λ = load-speed constant of the servo-actuator reflected at the point where the deflection of the servo is measured [lb-sec/in.].

Eq. (4) is the same type of approximation as eq. (2). From the above expressions, it may be seen that the servo stiffness is also governed by a third factor λ, which represents physically the basic characteristics, quality, and capacity of the servo-actuator.

The stiffness of the servo is very important in both positioning and continuous contouring control. In positioning control, the minimum requirement is to design a servo with sufficient static stiffness to ensure that the deflection of the servo under static friction load is within the specified accuracy. If the servo is used to hold the machine member against cutting loads of an impact nature, a high dynamic stiffness may also be required. Dynamic stiffness is particularly important in designing a milling machine performing a continuous contouring operation. As is commonly realized, the milling process is actually a series of impact loadings, so that surface finish and cutter life are directly governed by the dynamic stiffness of the servo. This requirement is further accentuated by the basic motive in using automatic control, with which the machine tool is expected to produce finished parts more rapidly and under a heavier cutting load, as operation is no longer governed by human responses or delayed by human decisions.

(*To be concluded*)

Water-Soluble Cellulose Ethers as Binders for Foundry Sands

By R. Morén. (From *Gjuteriet*, Vol. 47, No. 8, August 1957, pp. 157-165, 19 illustrations.)

WATER-SOLUBLE cellulose ethers are widely used in different branches of industry as binders, thickeners, emulsifiers, and stabilizers. Cellulose ethers have in recent years also found a significant new market within the foundry field. The products are applied as core and moulding-sand binders, in conjunction with synthetic resins, core oils, and air-setting oils, and as an additive to improve the collapsibility of cores and moulds made of clay-bonded sand, cement sand, and CO_2 sand.

By varying the conditions under which the cellulose ether is produced, it is possible to modify important properties such as viscosity in water solution. Unlike starch, dextrin, and other similar products, water-soluble cellulose ether does not have any tendency to turn sour, to mould, or to ferment under normal conditions, and can be produced in qualities that remain constant.

Cellulose Ether in Combination with Synthetic or Natural Resins to Unit Binders

It has long been known that cellulose ethers have a number of important disadvantages if they are used without suitable strengtheners, i.e., (1) a large proportion of water must be added to the sand ; (2) the cores tend to have a low dry strength and brittle edges ; and (3) in medium and heavy castings, those parts of the core which are located opposite to the ingates are easily destroyed by metal erosion, this being caused partly through lack of strength of the core and partly through too rapid decomposition of the binder. In 1951, experiments were started in Sweden to investigate the possibilities of strengthening soluble cellulose ether, primarily ethyl-hydroxyethyl cellulose, by combining it with other products such as synthetic resins in powder form. The aim was to find the most suitable additives which, at the same time, were as cheap as possible. By utilizing all feasible combinations existing to-day, it is possible to retain the attractive characteristics of a sand bonded with cellulose ethers, i.e., high green strength and toughness, good plasticity, low gas content, and excellent collapsibility, and at the same time improve dry-strength control and collapsibility to suit actual needs. The difference in baked transverse strength at various temperatures between ethyl-hydroxyethyl cellulose as sole binder and in combination with melamine is illustrated in Fig. 1. Among the many products which have been tried to improve strength, melamine and urea-formaldehyde resin have proved especially suitable, but other synthetic resins have also given the desired effect. By selecting the most appropriate additives and trying out the best proportions, it has been possible to arrive at certain standard products which are particularly suitable as " unit " core binders. The quantity normally added to the sand is about 0·8 to 1·5%, with a moisture content of about 4 to 5%.

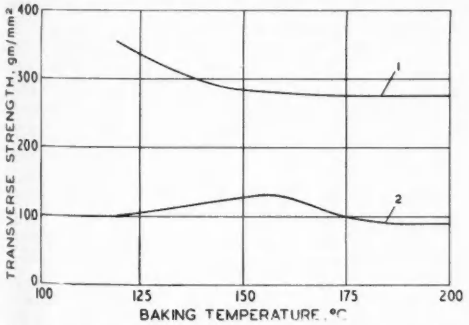


Fig. 1. Baked transverse strength as a function of baking temperature, with a baking time of 1½ hr.
Curve (1): 50% ethyl-hydroxyethyl cellulose + 50% melamine (moisture content = 4·5%).
Curve (2): Pure ethyl-hydroxyethyl cellulose (moisture = 7·2%). Addition of binder in both cases = 1%.

The baked transverse strength of sand bonded only with ethyl-hydroxyethyl cellulose attains a maximum of about 130 to 140 gm/mm² (185 to 200 psi), with a moisture content of 6% and with a 1·15 to 1·4% addition of the cellulose. With a 1% addition, the strength is slightly less than 1·30 gm/mm², falling to about 85 gm/mm² with a 0·5% addition. If, however, the ethyl-hydroxyethyl cellulose is combined with melamine, a maximum baked transverse strength of about 390 gm/mm² is obtained with a 1% binder consisting of about 20% of the cellulose and 80% melamine, with a moisture content of 4·5%.

However, for most purposes, it is desirable not only to obtain a high dry strength, but at the same time as high a green strength and toughness as possible. Therefore, due consideration must be given to green compressive strength and shatter index, as well as to dry strength, when comparing different proportions between ethyl-hydroxyethyl cellulose and melamine. Investigations show that the ideal combination, with a moisture content of 4·5%, is a 1% binder containing from 60 to 80% ethyl-hydroxyethyl cellulose and 40 to 20% melamine, giving a green compressive strength of from about 0·6 to 0·7 gm/mm² and a shatter index from about 65 to 70%. This also agrees with industrial experience.

It has been found desirable to produce core binders based on cellulose ethers and synthetic resins in the form of a powder, to facilitate handling both in shipping and use. The powder should be such that it can be stored for an unlimited length of time.

When using these unit binders, the desired quantity is mixed dry into the sand. The necessary amount of water is then added and the mix mulled to full strength. The time of mixing is the same as for cereal binders, provided that the cellulose ether is in the form of a fine, quickly dissolved powder in which the synthetic resin has been evenly distributed. The variation of green and dry strengths as a function of the amount of binder added for different moisture contents is shown in Figs. 2 and 3, in which the binder consists of a commercial compound of ethyl-hydroxyethyl cellulose and melamine.

With the practical experience now available it is possible to manufacture combinations of cellulose ethers and synthetic resin suitable for all kinds of metal castings, e.g., aluminium alloys, magnesium alloys, copper alloys, tin, lead, grey iron, malleable iron, and steel. Cores made with these binders are baked in ovens in the usual way. Since cellulose ether can be dried dielectrically with advantage, cores produced with cellulose ether combined with synthetic resin may be quickly baked in a high-frequency oven.

By addition of a hardener and by proper balancing of cellulose ether and resin, it is possible to obtain a sand from which small cores can be made without baking. These cores are air-setting and harden after a few hours.

The gas content of core sand containing a binder

based on cellulose ether and synthetic resin is very low. For example, with a 1% addition of a commercial binder, the gas content is only about 13 cc/gm of the core sand. A core made with cereal binder and core oil normally has a gas content of 20 to 30 cc/gm.

It is usually desirable that the core collapses completely after the casting has solidified. This is especially important with light alloys and thin-walled iron castings, which are particularly susceptible to cracking due to contraction. The same applies to all castings where the core is more or less completely surrounded by metal, and in all cases where it is difficult to remove the core sand completely by mechanical means. Cellulose ethers combined with synthetic resin are, in this respect, superior to all other known types of binders.

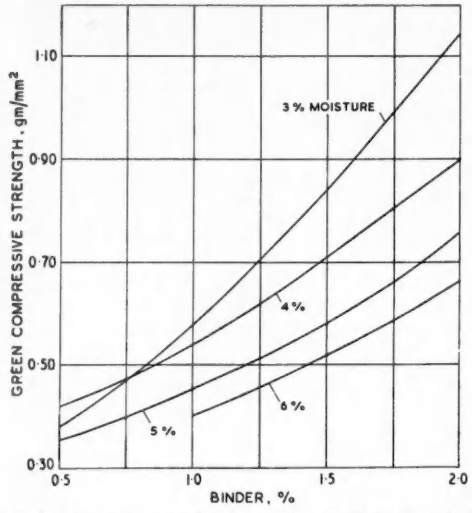


Fig. 2. Green compressive strength as a function of the amount of binder, for different moisture contents.

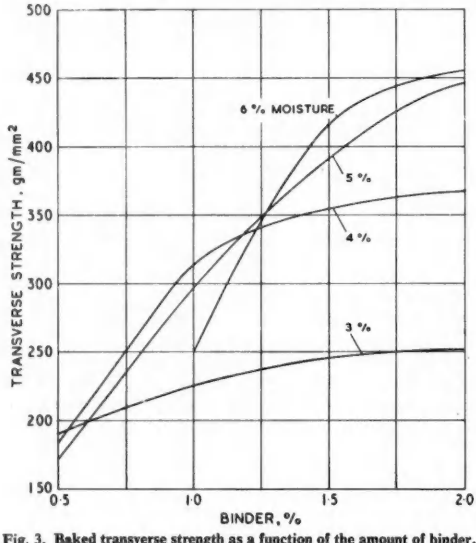


Fig. 3. Baked transverse strength as a function of the amount of binder, for different moisture contents.

With regard to the comparative properties of different soluble cellulose ethers combined with melamine, tests on two types of methyl cellulose have shown that this material gives unsatisfactory dry strength and is therefore unsuitable. Also, as carboxyethyl cellulose is extremely hygroscopic, it is not acceptable as a binder ingredient. The cellulose ethers which were tested and proved to be suitable as binders in combination with melamine are ethyl-hydroxyethyl cellulose, methyl-hydroxyethyl cellulose and hydroxyethyl cellulose.

Water-Soluble Cellulose Ethers in Cement Sand

As long ago as the 1940's, it was discovered in Germany that water-soluble cellulose ethers were suitable additives to cement sand. By such additions the sand attains a desirable green strength, and at the same time collapsibility is considerably improved. As the cellulose ether delays the setting of the cement, it is necessary to add an accelerator, e.g., calcium chloride, particularly if hardening takes place without heat, which is normally the case in cement moulding sand.

It has been shown that combinations of cellulose ethers and synthetic resin in cement sand give a still better dry strength than cellulose ethers alone. Addition of calcium chloride results in rapid hardening, which often enables the pattern to be stripped from the mould immediately. Under favourable conditions, it is possible to pour the casting only 24 hours after moulding.

Water-Soluble Cellulose Ethers Replacing Cereal Binders in Oil-Sand

Certain cellulose ethers can advantageously replace cereal binders in oil-sand. If, for example, ethyl-hydroxyethyl cellulose is substituted for starch, it is necessary to use a quantity corresponding to only 15 to 20% of the usual amount of starch to obtain the same green strength and roughly the same dry strength. If ethyl-hydroxyethyl cellulose is used in conjunction with linseed oil, the dry strength is somewhat lower than with starch. This depends partly on a decrease in the total amount of binder added. It is therefore necessary somewhat to increase the quantity of linseed oil. In combination with many other core oils, ethyl-hydroxyethyl cellulose often gives a dry strength which is about the same as with cereal binders.

It should be mentioned that products based on cellulose ethers and synthetic resin also can be used in oil-sand, and in such cases good surface hardening can be obtained in the green state. This diminishes the risk of dimensional changes during baking.

Baked oil-sand cores containing starch binders stored in damp places readily absorb large quantities of moisture. This happens, for instance, when cores are left for some time in a green sand mould before pouring. Here the cores lose part—and under unfavourable conditions a very large part—of their dry strength, besides giving off more gas when surrounded by molten metal.

A simple check on standard transverse cores shows that a linseed-oil core with starch, and to a still higher degree such a core containing dextrin, is soft and plastic after 24 hours in a green sand mould. Very little of the original dry strength remains.

A linseed-oil core with ethyl-hydroxyethyl cellulose added for green strength absorbs only about half the amount of moisture absorbed by a linseed-oil core containing starch when submitted to a similar test. After 24 hours in a green sand mould, a baked transverse-test core made in sand with ethyl-hydroxyethyl cellulose and

linseed oil is hard and has a transverse strength at least twice as high as the starch/linseed-oil core.

Not only dextrin and starch have a tendency to absorb moisture to such a high degree that only 10 to 20% of the original day strength remains in a standard test core after storing 24 hours in a green sand mould. Cores made with carboxyethyl cellulose are highly hygroscopic. Although methyl cellulose and methyl-hydroxyethyl cellulose absorb comparatively small amounts of moisture, their dry strength is unsatisfactory.

In view of the fact that, according to the experimental data obtained, hydroxyethyl cellulose gives a green strength of only 0·32 gm/mm², as compared with 0·59 gm/mm² for ethyl-hydroxyethyl, it is obvious that the latter product is preferable in this case.

Cellulose ethers generally require a somewhat higher moisture content than starch to give the best green strength, and for this reason they have been difficult to use in core sand with a moisture content below 2%. However, new investigations, not yet finished, show that if, through some suitable additive, the pH-value of the core sand is kept slightly on the alkaline side, e.g., pH 7 to 9, it is possible to use ethyl-hydroxyethyl cellulose in the same way as starch, even where the moisture content is low. Such an additive also increases green strength and toughness.

Thus, according to the desired properties of the cores, cellulose ether, together with core oil, can either be used in its pure form or be combined with other substances e.g., sodium metasilicate, which is mixed with cellulose ether in a small quantity so that a suitable pH-value is obtained in the sand.

Tests show that green strength and shatter index in oil-sand with pH-controlled ethyl-hydroxyethyl cellulose are not only superior to those of starch but also to those of other tested water-soluble cellulose ethers.

Ethyl-hydroxyethyl cellulose and even other cellulose ethers give off smaller quantities of gas than do starch and dextrin. The necessary cellulose-ether addition to oil-sand is often considerably smaller than the amount of cereal binder needed to obtain the same green strength. It is for this reason that the gas content must be considerably smaller.

The amount of gas given off per gram of core sand containing pH-controlled ethyl-hydroxyethyl cellulose and linseed oil is compared with core material containing starch and linseed oil in Figs. 4 and 5. From Fig. 5 it can be seen that the rate at which gas is emitted is realtively slower in the case of ethyl-hydroxyethyl cellulose. The two types of core are approximately comparable with regard to green and dry strength.

When used as a binder to give green strength, cellulose ether combined with core oil has the following advantages, compared with starch or dextrin:—

(1) It absorbs considerably less moisture from the surroundings.
(2) It has an appreciably lower gas content.
(3) Collapsibility after casting is appreciably improved.
(4) A smaller quantity of binder is needed.
(5) Improved emulsification of the oil can be observed, resulting in noticeably smoother surfaces, especially with low binder contents.

The Use of Cellulose Ether to Improve Collapsibility in Other Core and Moulding Sands

In many cases it is desirable to increase the collapsibility of core and moulding sand after pouring. This problem exists, for instance, in cores made according to

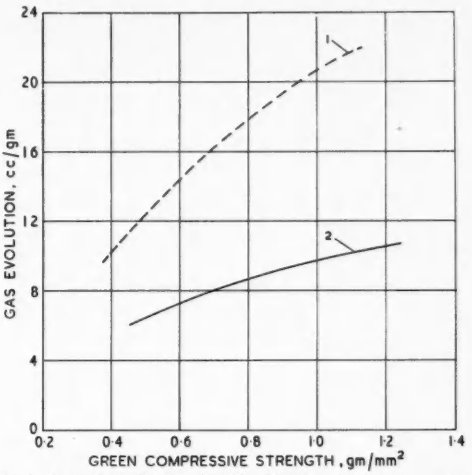


Fig. 4. Gas evolution from core sand as a function of green compressive strength in cores containing 2% moisture, 1% linseed oil, and (curve (1)) starch, or curve (2)) 90% ethyl-hydroxyethyl cellulose and 10% sodium metasilicate.

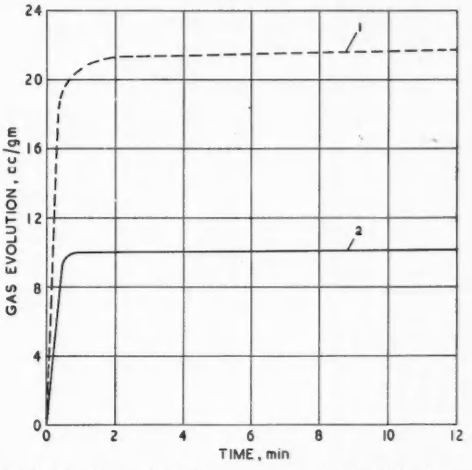


Fig. 5. Rate of gas evolution from core sand containing 2% moisture, 1% linseed oil, and (curve (1)) starch, or (curve (2)) 90% ethyl-hydroxyethy cellulose and 10% sodium metasilicate.

the CO_2 process or in clay-bonded cores, e.g., for ingot moulds. Good collapsibility is also important in water-jacket cores for combustion engines, in making larger thin-walled parts in light alloy and cast iron, and, as mentioned earlier, in cement-sand moulding.

In the CO_2 process it is advisable to use pure cellulose ether, e.g., ethyl-hydroxyethyl cellulose, as an additive in the sand up to 1·5% in difficult cases. Some of the dry strength is lost, but this can be compensated by the addition of slightly more sodium silicate—in practice it is common to use 4 to 5% sodium silicate, together with 0·2 to 1·5% ethyl-hydroxyethyl cellulose calculated on the sand weight.

In clay-bonded cores for ingot moulds, 0·1 to 0·3% pure ethyl-hydroxyethyl cellulose is added. In this way it is easy to remove both mould and core sand together on the shake-out.

RUSSIA

Improved Method of Pressing with Rubber Dies

By G. Yu. Pokonechnyi. (From *Vestnik Mashinostroyeniya*, No. 6, 1957, pp. 43–45, 9 illustrations.)

Existing methods of blanking components in a press tool with a rubber die have a number of substantial drawbacks. These include low output, rapid deterioration of comparatively expensive rubber, excessively wide spacing (15 to 20 mm) between the blanked components, bad quality of the sheared edges, and the impossibility of simultaneous piercing of small holes or of blanking components with sharp corners in their contours. This article describes a new type of rubber die for blanking on mechanical presses, which eliminates some of these drawbacks and which has proved its value in actual service.

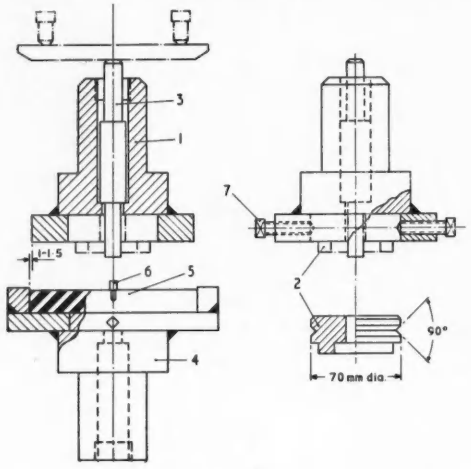


Fig. 1.

The punch consists of a die or template of from 4 to 8 mm in thickness, and the bed, 15 to 20 mm in thickness, is a cushion of cord-reinforced rubber made of old motor-car tyre covers. A variety of components can be pressed in a general-purpose press tool (Fig. 1), in which, within a certain range of sizes, only the template has to be interchanged. The top bolster (1) is fixed in the press ram and carries the template (2) and ejector pin (3), the latter serving to strip the off-cut after punching the central hole in components like washers. The lower bolster (4) is mounted on the table of the press, and the rubber cushion (5) is positioned between two flat bars. The strip is advanced by one pitch by means of the stop (6). The shanks of the top and bottom bolsters have the same diameter, so that they can be interchanged when any particular work requires the rubber cushion to be on top. For pressing washer-type components of small size, the template is of single-piece construction, with a spigot set in a recess in the upper bolster (1) and secured by two screws (7). Special provision is made to facilitate stripping of off-cuts from the template and to reduce the width of the spacing between blanked components to only 4 to 6 mm.

For blanking a large number of steel components, the template is made of tool steel, quenched to a hardness of 58 to 62 Rockwell C, its operating surface being ground. For pressing non-ferrous components, the template can be made of ordinary structural steel. Templates for large-size components or those of complex shape are made of low-carbon steel plate of from 6 to 8 mm in thickness, case-hardened and quenched. For blanking sheets of from 0·3 to 0·4 mm in thickness, it has been found that a template thickness of only 4 mm is quite satisfactory. Different types of templates can be used for blanking, piercing, flanging, bending, and other operations. The thickness of steel stock can attain 1 mm (or even 1·5 mm for mild steel), and that of non-ferrous alloy stock up to 2·5 mm. If the rubber cushion is boxed in on all four sides, even greater thicknesses can be pressed.

The life of the rubber cushion amounts to several thousand components and can be increased if the same cushion is first used for blanking small components and then larger components, or if, during pressing operations, the position of the cushion relative to the template is varied.

If the template has a hole larger than the outside diameter of the block, the template can be fixed to an intermediate plate of from 5 to 7 mm in thickness, which is then attached to the block. To improve stock utilization, a number of templates can be attached to the intermediate plate. In this way, more economical tailoring is achieved for each set of components.

A number of small templates for pressing perforated types of components can be attached to the intermediate plate in various ways, i.e., by caulking, riveting, screwing, or welding. Templates with straight walls can be positioned with the help of the first experimental off-cut obtained after pressing, this off-cut itself acting as a template for positioning the dies, and being fastened, if desired, to the plate by screws. When pressing non-magnetic materials, use can be made of a plate which constitutes a permanent magnet, holding the template sufficiently securely until the relative displacement between different templates is prevented by means of the first off-cut.

Electromagnetic mounting of templates to a plate has special advantages, as it is an easy matter to fix the templates on the plate in any required position and hold them in place with an electromagnet whose core is in contact with the plate. Furthermore, the templates and the magnet can be positioned, as desired, on either the upper or lower bolster, depending on convenience in operation.

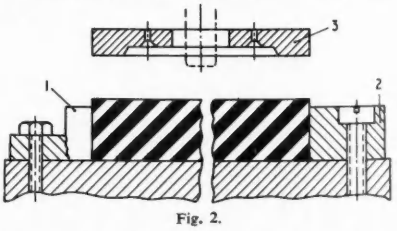


Fig. 2.

Compound pressing can also be carried out by means of the press tool shown in Fig. 2, in which the bed comprises the displaceable knife-edges (1) and (2), which are set up with a definite clearance along the template contour (3). The forming operation following blanking is carried out in a rubber die.

Compound pressing with rubber offers various possibilities. Thus, with an inclinable table or with removal of the blanked component and off-cut by means of compressed air, rubber pressing can be mechanized and rendered automatic.

5th EUROPEAN MACHINE TOOL EXHIBITION

In the following pages, details are given of a number of items shown at the 5th European Machine Tool Exhibition, which is being held this year from September 15 to 24 in the Exhibition Grounds of the Deutsche Messe- und Ausstellungs- AG, Hanover. A further selection will be included in our October issue.

Among the comprehensive selection of hobbing, vertical and horizontal gear-generating, rack-generating, and gear-shaving machines, together with a range of hobs, cutters, and shaving tools, **W. E. Sykes Ltd.**, of Staines, Middlesex, are exhibiting the first production model of the Sykes VS4A fine-pitch gear-shaving machine (Fig. 1). This gear-tooth finishing machine is specially designed for relatively small and accurate work from $\frac{1}{4}$ to 4 in. in diameter. The coarsest pitch which can be accommodated is 16 D.P., the maximum face width of the component being 1 in. Gears on shafts up to 10 in. in length may be shaved, unless the gear is at one end of the shaft, in which case the length should not exceed 6 in. The machine occupies a very small floor-space and is rigidly constructed for precise working and high standards of finish. The design permits automatic loading to be employed or, when hand loading is used, operation may be safely entrusted to unskilled labour. The work and shaving tool are always clearly visible through a transparent window in a movable guard.

Fig. 1.

The work is placed between the centres and, on simultaneously pressing the two "Start" buttons fitted with a safety electrical interlock, the automatic cycle commences. The tool and work revolve and the component traverses across the tool face. At the end of the pass the direction is reversed and, in four complete traverses, the component is shaved to size. At each traverse the automatic infeed reduces the centre distance between the work and the tool until the finished dimension is reached. The machine stops at the end of the cycle. Setting is particularly simple and accurate, as a dial gauge and a micrometer control permit precise sizing of the gear. The tool angle is set with a sine-bar device which enables extreme accuracy to be obtained. Cycle times vary from 13 to 45 sec, depending on the nature of the component and the material. Four tool speeds are provided, ranging from 110 to 373 rpm, and the number of reversals can be varied between 5 and 10 per minute. The traverse of the component can be easily adjusted up to a maximum of 1 in. in $\frac{1}{16}$ in. increments. The total cutter infeed is 0·01 in. and is adequate for all components coming within the scope of fine-pitch gear shavers.

An interesting exhibit from **Präzisions-Technik G.m.b.H.**, of Wertheim, Germany, is the PeTeWe projection form grinding machine, two models of which, the PES.3dII (Fig. 2) and the PES.4u, are being

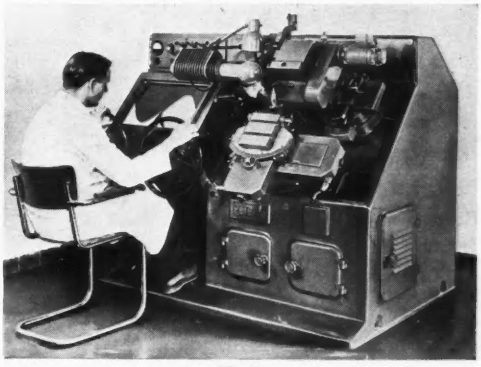


Fig. 2.

demonstrated. On these machines, the drawing, the workpiece, and the grinding wheel are all shown on the same screen to a magnification of ×50 or ×20 in the case of the 3d machine, and ×10, ×20, or ×50 on the 4u type. A magnification of ×100 can be supplied on this machine, if required. The operator of the PeTeWe machine guides the projection of the grinding wheel along the drawing by movement of the two large control wheels. The left-hand wheel controls horizontal movement, and the right-hand wheel movement of the grinding wheel vertically to the workpiece. In actual operation, the integration of the grinding wheel feed becomes one process, providing extremely high-precision results. The whole progress of the operation can be checked by the operator from his seated position, and accuracy to the order of 0·00008 in. at ×50 magnification is obtainable.

In addition to a range of lathes, vertical milling and boring machines, automatic rotary tables, etc., **Minganti**, of Bologna, Italy, are exhibiting their automatic turret lathes, models TM 80 P and TM 100 P, the former of which has a spindle bore diameter of 80 mm and the latter 100 mm. This type of lathe (Fig. 3) has been designed for high-speed turning and incorporates a number of features to ensure high efficiency and productivity, including push-button preselection of speeds and feeds.

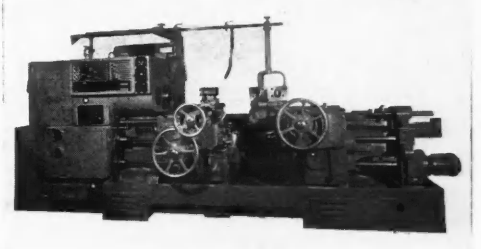
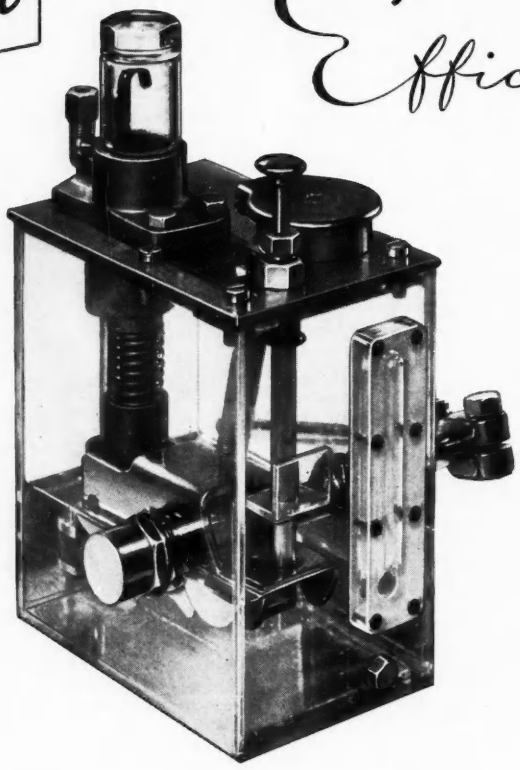


Fig. 3.

Manzel

Efficient



MECHANICAL LUBRICATORS

HAPPY CHIEF

Happy Chief he who knows
from his Lube's modern oils flow,
No streaming or clouding
No water in the sight
Or Glass Tubes to shatter
When the pressure's getting tight
Visual drops to every station
No magic wand or transformation
—Modern Manzel Lubrication.

Manzel

British Manzel Oil Pump Co., Durranhill Engineering Works

Tel.: 21418/9 **CARLISLE** Grams.: Lubrifiers

Twelve spindle speeds are available, with a maximum of 1500 rpm for the TM 80 model or 100 rpm for the TM 100, while sixteen automatic feeds can be obtained for the lower carriage and eighteen for the front carriage. A wide range of ancillary equipment is available, including pneumatic clamps and self-centering chucks, special tool-holders for multiple-cutting operations, and hydraulic copying devices.

Exhibits by **Wickman Limited,** of File Hill, Coventry, cover a wide range and are a representative selection of some of the latest developments in the application of automatic machines to modern production problems. As such, exhibits include multi-spindle automatics, bar automatics, grinding machines, and boring and turning mills, all designed to increase flexibility and production.

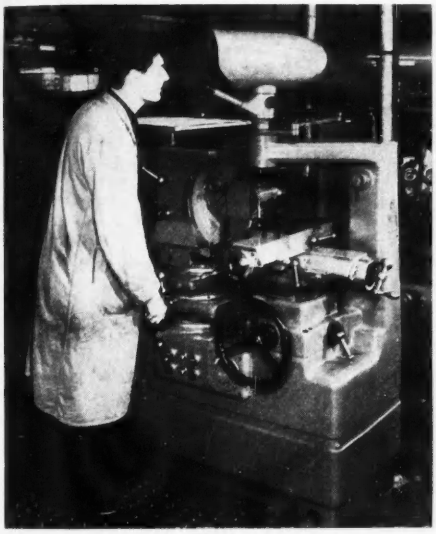


Fig. 4.

Of these, an interesting example is the Wickman optical profile grinding machine shown in Fig. 4. With this extremely accurate form grinding machine, which is unusually easy to operate, a drawing of the required form, at a magnification of $\times 50$, is made on special dimensionally stable aluminium laminated paper, reduction of the form to the requisite size being effected by a pantograph arm which positions the objective of a microscope directly above that portion of the work to be ground. The grinding wheel, also visible in the microscope, is then brought to the work by operating the control wheels until the wheel is seen to touch the crossing of two hair-lines engraved on the microscope viewing lens, which is always the limit of grinding. A small circular screen is provided for rough checking; this repeats the image visible through the microscope and, in contrast with contemporary large-screen methods of projection, uses only that part of the screen, i.e., the exact centre, in which the image is in exact focus. This system is extremely accurate (better than 0·0005 in. under ordinary conditions), and accuracy is not impaired by wheel wear.

Part of the simplicity of the machine is due to the design of the wheel-head slides, which allow angular forms to be ground by direct traverse, and to the viewing and work illumination, which not only give a clear, accurate view in normal daylight, but also allow clearance angles to be ground without loss of accuracy due to poor illumination. The machine can be used to grind intricate forms to very fine tolerances in all materials, and the use of the available attachments, which include a circular-grinding attachment, cutter-indexing attachment, index-

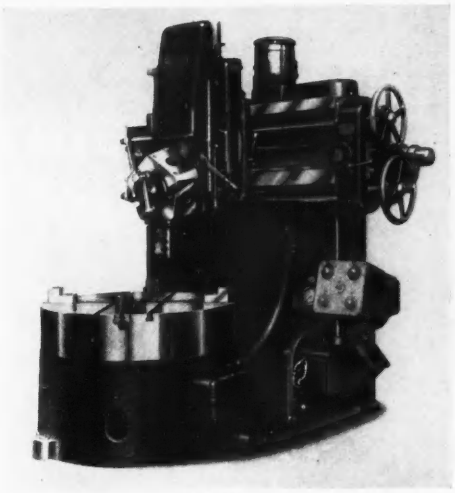


Fig. 5.

ing attachment, and an $\times 50$ microscope, extend the scope of the machine still further.

Another interesting Wickman exhibit is a 48-in. boring and turning mill, manufactured by their associated company, **Webster and Bennett Limited,** of Coventry. This machine (Fig. 5), which is the middle member of a range which includes 36-in. and 60-in. machines, has a chuck diameter of 48 in. and will take work up to 53 in. in diameter and up to 35 in. in height under the turret. Of the drives available, comprising special high-speed, high-speed, normal-speed, low-speed, and special heavy-duty, the particular machine exhibited is fitted with a special high-speed drive, giving a speed range of 8·6 to 192 rpm and a feed range of 0·004 to 0·197 in. per revolution, each range having twelve steps. This particular machine is also fitted with automatic electric trips, which can be used as trips, as dead stops for sizing by manual control, or as safety limit-switches.

The first hydraulic "Multiform" machine in production form is being shown in operation by **Heenan & Froude Limited,** of Worcester. This entirely new method of cold strip forming, which was introduced by Heenan & Froude, employs hydraulic operation and dispenses with mechanical movement, including the actual tool-slides

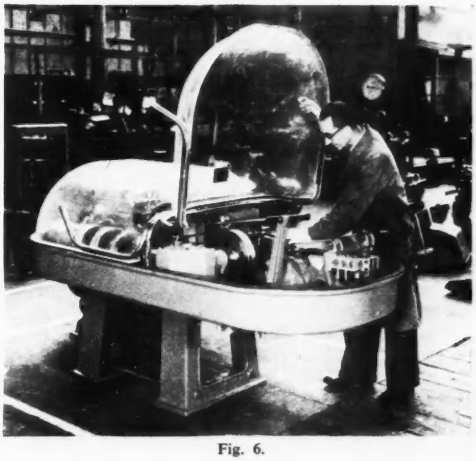
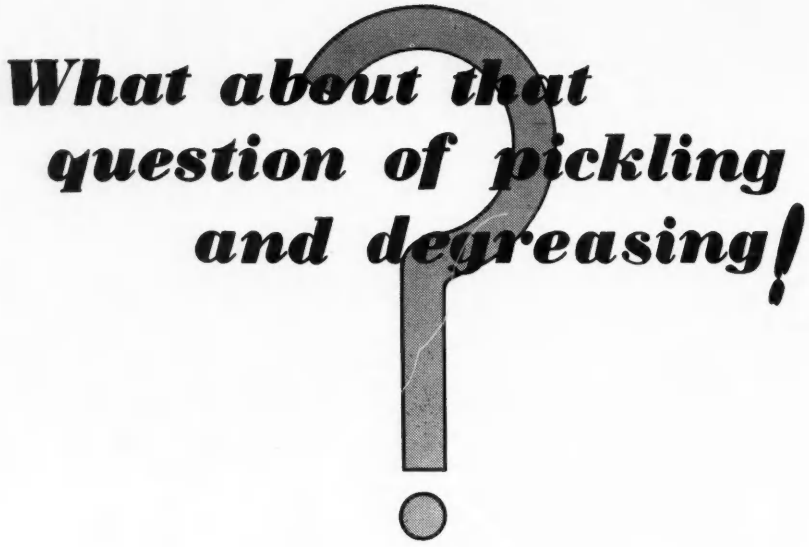


Fig. 6.

What about that question of pickling and degreasing?



Watch wheels or Wagon wheels?
Stove parts or Steel Roll Chocks?
Cylinder blocks or Colliery Equipment?
Refrigerators or Repetition Pressings?
Whatever the product—it needs
cleaning with a CURRAN DEGREASING,
PICKLING and WASHING PLANT.

We design and build machines
to suit every requirement—
not only that—we supply all
Industrial Cleaning Solutions as well.
In addition a technical staff is
at your disposal for advice—
truly a comprehensive CURRAN SERVICE.

Write for full details.

Telephone: CARDIFF 33644

EDWARD CURRAN ENGINEERING LTD PROCESS PLANT DIVISION **CARDIFF · G^T. BRITAIN**

themselves. Since the prototype machine was first exhibited at Olympia last year, a number of modifications has been introduced, chief of which is the substitution of a geared electric drive for the camshaft, in place of the original hydraulic drive. As a result, greater convenience of control has been obtained, and push-button inching can be carried out from practically any position around the perimeter of the machine.

The principle of operation of the Heenan Hydraulic Multiform is based on a servo-actuated valve operated by the master camshaft and working on a few pounds pressure, which is converted into the full tonnage of the machine at the operating stations. The cams actuate small levers which are coupled to flexible members connected to the servo-valves. With this arrangement, it is possible to have extremely accurate control of the servo-valves with only a very light pressure on the cam faces, permitting perfect control of each slide. A set of standard cams is included with each machine, profiled to give standard slide actions to suit most cases. When special cams are needed, these can be made at almost negligible cost by the tool-setter.

Two different models of the " Multiform " are being exhibited, i.e., the S$\frac{3}{4}$" and the S1$\frac{1}{2}$", capable of handling maximum widths of strip material of $\frac{3}{4}$ and 1$\frac{1}{2}$ in. respectively. The Multiform S1$\frac{1}{2}$" (Fig. 6) is being shown producing a copper electrical contact for one operation which previously required six operations by other methods.

A representative example from the range of Innocenti/GWB milling and boring machines is being exhibited by **Innocenti**, of Milan, and has been arranged to carry out demonstrations of the machining of alternator rotors.

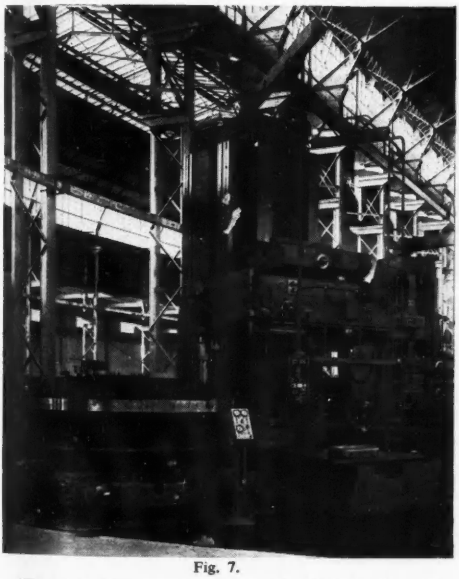


Fig. 7.

These machines, an example of which is shown in Fig. 7, differ from conventional types in the application of new methods designed to confer considerably increased scope of production, precision, and performance. Thus, they incorporate high spindle power as the result of very short and highly efficient kinematic chains, with constant speed variation ; independent and steplessly variable control of all feed movements ; the use of a movable headstock ; automatic high-precision stops ; and a centralized pendent control, which controls all movements, including the precision stops and the locking of the carriages.

Exhibits by **Maschinenfabrik Heid A.G.**, of Vienna, include the " Neomat " centre lathe (Fig. 8). In this straight-bed machine with variable centre height, the design is such that, when the headstock and tailstock, which are mounted on inclined bases, are moved upwards and to the rear to accommodate larger diameters, the resulting cutting pressure never falls outside the front shear. Furthermore, as the turning axis moves in this direction, it approaches nearer to the gravity axis of the bed, thus lessening the tendency of torsional stresses to twist the bed in an anticlockwise direction.

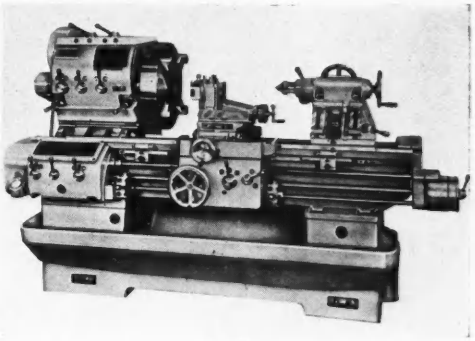


Fig. 8.

Reversal and braking of the spindle are effected by means of Heid electromagnetic multi-disc clutches without slip-rings, these clutches being self-compensating for wear and hence requiring no periodic attention. Spindle control is obtained by levers conveniently positioned at the headstock and apron, with four positions on the quadrant, giving positive control of forward spindle movement, neutral, brake, and reverse spindle movement.

Exhibits by **C.V.A. Jigs, Moulds and Tools Limited** include a wide range of lathes, vertical and horizontal milling machines, and single-spindle automatic screw machines. Of these, the No. 8 automatic $\frac{1}{2}$-in. capacity screw machine (Fig. 9) has been entirely restyled and now incorporates such features as a smooth timing-belt transmission, which is an exclusive toothed-belt drive providing a positive non-slip transmission, free from shock and stretching. Furthermore, a new gearbox, providing 18 turning speeds up to 7250 rpm and 240 threading speeds, is fitted, while a new change-feed gearbox gives a choice of 66 cycle times, ranging from $\frac{3}{4}$ to 64 sec. Other

Fig. 9.

Churchill

'OSB'

HORIZONTAL SPINDLE SURFACE GRINDING MACHINE

This machine is designed for work requiring extremely accurate and highly finished flat surfaces. Besides being ideal for toolroom work and for die grinding, the Model 'OSB' can be used to advantage in the production line. High rates of output are obtainable. Built in three sizes with work tables 30in. by 10in., 42in. by 10in. and 60in. by 10 in.

Easy and simple operation.
Built-in motor drive to grinding wheel spindle. Motorised automatic pump lubricating system and simple bearing assembly give a high precision spindle capable of heavy grinding cuts.
Variable hydraulic cross feed to wheel. Pre-set automatic cut-out and automatic reverse.
Fine and coarse vertical feed.
Massive cross slide underneath wheelhead column gives large area of support and maximum stability.
Hydraulic table traverse up to 90 feet per minute. Hand traverse interlocked with hydraulic control.
Permanently protected precision ground table slideways.
Table traverse ways, wheelhead cross slideway and cross feed gears and bearings automatically lubricated from oil supply independent of hydraulic system.

BRITISH MACHINE TOOLS EXPORT LTD.

THE CHURCHILL MACHINE TOOL CO. LTD. BROADHEATH, NR. MANCHESTER

Telephone : Altrincham 3262. *Telegrams :* Churchale, Manchester

Export Sales Organisation : **ASSOCIATED BRITISH MACHINE TOOL MAKERS LTD. LONDON, BRANCHES AND AGENTS.**

Home Selling Agents : **CHARLES CHURCHILL & CO., LTD., BIRMINGHAM AND BRANCHES.**

PRECISION *plus* PRODUCTION

C662 A

innovations include extra power available from a reversible 3-hp motor, which is foot-mounted inside the cabinet and drives the gearbox via multiple V-belts, and a new camshaft-drive needle-bearing transmission through heavy-duty oil-immersed worm gearing. A feature of the new timing-belt transmission is that, by virtue of its positive grip, the full power of the motor is always available at the cutting tool, permitting the use of carbide tooling, where desirable.

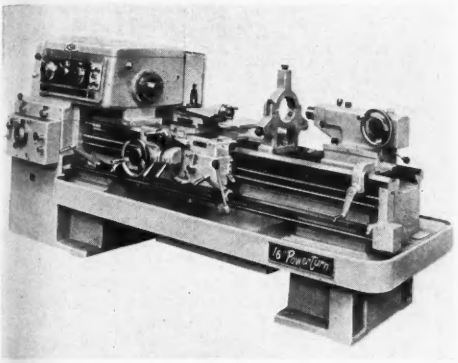


Fig. 10.

Another new C.V.A. exhibit, in this case manufactured under licence from the **Lodge & Shipley Co.**, of Cincinnati, Ohio, is the " Powerturn " 16 × 78 in. lathe with a swing over the bed of 20½ × 78 in. between centres. As in other "Powerturn " models, this lathe (Fig. 10) is provided with spur gearing, oversized precision bearings, and alloy-steel shafts, to give a positive and accurate drive through a range of 24 spindle speeds up to 2000 rpm and 20 hp. A new speed dial makes speed indication virtually automatic, as the machine calculates and indicates the proper speed. The head also shows allowable horsepower on a built-in ammeter. Other features include an automatic spindle brake, with quick release ; automatic lubrication, with full-flow cartridge-type oil filters ; and conveniently grouped controls.

Exhibits by **The Newall Engineering Co. Ltd.**, of Peterborough, comprise a range of high-precision jig boring and drilling machines, optical rotary indexing tables, and auxiliary equipment specifically manufactured for tool-room use and for production jig boring.

An exceptionally interesting exhibit is the " Spacematic " automatic-positioning jig borer (Fig. 11). In addition to a number of design modifications which have been incorporated since it was exhibited last year at the International Machine Tool Exhibition, Olympia, a two-

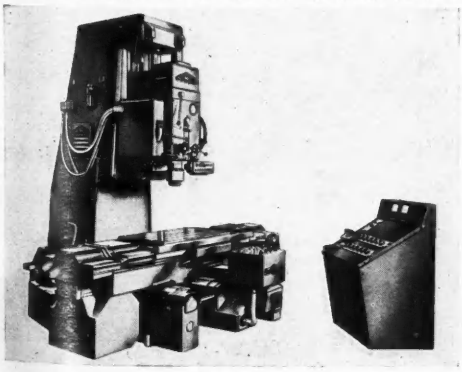


Fig. 11.

dimensional tracer control for highly accurate copy-milling has been developed, further extending the capabilities of this machine.

Another recent Newall production on display is the " Optiset ", a medium-capacity jig borer incorporating an optical system for co-ordinate selection designed and manufactured by **Optical Measuring Tools Ltd.**, one of the Newall Group of Companies.

In addition to a full range of production boring equipment designed for use with the above machines, the latest O.M.T. optical rotary indexing tables are also being demonstrated, including the 30-in. model with a scale reading direct to 1 sec of arc and with a power-operated platen ; the 16-in. inclinable table, a new development with scales reading direct to 1 sec of arc for rotary and inclinable movements ; and a 16-in. projection-type rotary table, available with a scale reading to 2 or 10 sec of arc, as required.

A complete range of their multiple-spindle vertical and horizontal drilling machines, together with examples of their single-spindle vertical and horizontal drilling and boring machines, is being exhibited by **Officine Rino Berardi**, of Brescia, Italy. All these machines are fitted with a hydraulic head movement capable of producing a comprehensive variety of automatic working cycles.

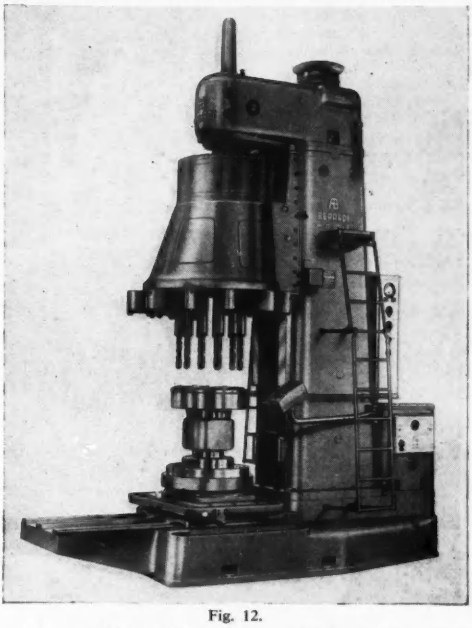
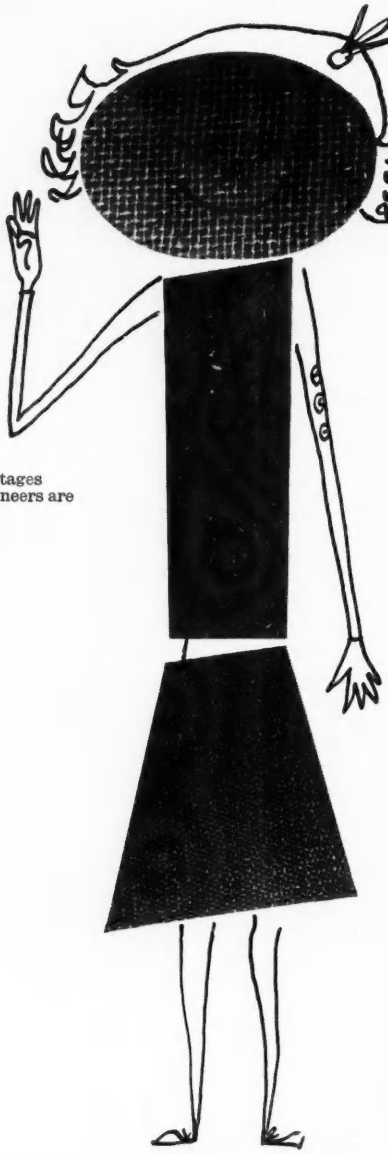


Fig. 12.

New exhibits will include examples from the range of V B IV vertical-column multiple-drilling machines, one of which, the V B IV L, is shown in Fig. 12. These machines, like other vertical-column multiple-drilling machines in the Berardi range, are fitted with a hydraulic feed control, giving a standard automatic cycle of fast approach, workpiece feed, stop at the end of travel, fast return, and stop. Speed change for all spindles is effected by pairs of assorted gears, and each spindle is arranged for individual speed changes with two ratios and neutral. Consequently, it is possible to have some spindles rotating at high speed, others at low speed, and still others stopped.

Other new Berardi exhibits include a range of drilling machines fitted with an automatic working cycle and hydraulic feed, i.e., the vertical type VA and the horizontal type OA, both of which are being shown for the first time. Two sizes are available for the vertical type,

Guides are made of Ferobestos



A glance at these unique advantages shows why more and more engineers are specifying Ferobestos.

great physical strength
high strength to weight ratio
high temperature resistance
low moisture absorption
good chemical resistance
high wear resistance
good electrical resistance
high dimensional stability
low coefficient of friction

The versatility of Ferobestos, an asbestos-reinforced plastic material, opens up an extremely wide range of engineering applications. As well as guides these include:—

Bushes
Coupling Discs
Bearings
Gears & Rollers
Piston Rings
Wearing Slippers
Mounting Pads
Compressor Blades
Thrust Washers

Ferobestos is available in a number of special grades including silicone impregnated for greater heat resistance and graphite impregnated for more efficient lubrication.

Ferobestos can be supplied from stock in sheets, rods, and tubes. Special mouldings, where quantity justifies the cost, can be made to order. Write for fully detailed and illustrated leaflets.

J. W. ROBERTS LTD

FEROBESTOS DEPARTMENT

Chorley New Road, Lostock, BOLTON. Tel: Horwich 840 · *Branch Sales Offices: LONDON, GLASGOW, BIRMINGHAM, LEEDS*

A Member of the Turner & Newall Organisation

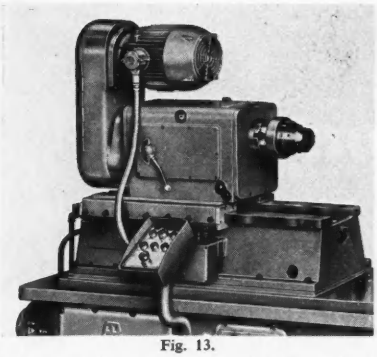


Fig. 13.

and four for the horizontal type, the OA II horizontal type being shown in Fig. 13. The horizontal models, incidentally, are so designed that they can be floor-mounted or installed on a movable bench-type base, the spindle being arranged to accommodate a direct drive from a flange-mounted motor or a belt transmission.

Exhibits from **Drummond-Asquith** include the Asquith H.R.G. type horizontal drilling, boring, and milling machine, manufactured by the **Asquith Machine Tool Corporation.** This machine (Fig. 14) is fitted with electronic control for the profile milling of the ports in Doxford liners, and incorporates a rotary headstock, a tailstock, and a workplate on which these are mounted. The horizontal traverse of the column along the bed is controlled by two motors ; the first is mounted on the slide for quick power traverse and the second on the column base for electronic feed, these electronic feeds being in addition to the normal mechanical feeds which are supplied for movement in this direction. The motions are interlocked, so that only one can be brought into operation, and a clutch is interposed in the feed system to select either feed or quick power-traverse motion. At the side of the slide and in line with the spindle, a bracket is positioned to carry a stylus roller. This roller contacts the template, which is mounted upon the liner itself, giving the necessary form for the milling of the ports. The water slots which run parallel to the axis of the liner and the radial slots which are interrupted by bosses can also be produced on this type of machine.

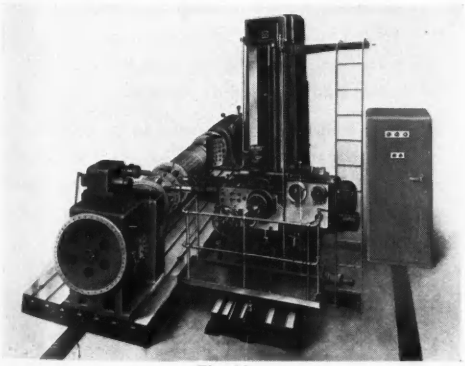


Fig. 14.

Another Drummond-Asquith exhibit is the Drummond " Maximinor " automatic multi-tool lathe (Fig. 15), manufactured by **Drummond Bros. Ltd.,** of Guildford, which, in this instance, is being shown specially tooled for the rapid production of automobile pistons and is an interesting example of extensive multi-tooling to perform a wide range of operations at one machining

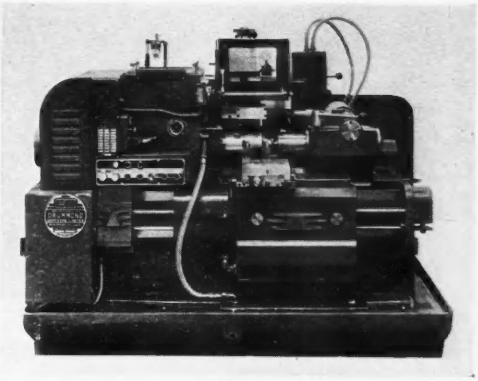


Fig. 15.

cycle. The rough piston is held against a location by a dummy gudgeon-pin and air-operated draw-bar. Tools on the front slide turn the piston wall to three diameters, while the rear tools rough-machine the grooves. The third or top slide carries two sets of tools for finish-turning the grooves and for breaking down the sharp edges to the grooves. The fourth slide is an independent motor-driven unit for facing the piston crown. By fitting a suitable former plate, the unit will turn concave, flat, or convex piston ends.

In addition to special-purpose machines and their model MN2U universal milling machine, which is being shown operating on an automatic cycle and fitted with a backlash eliminator, a spindle brake, feed brakes, a graduated scale, and an automatic spindle reverse, **Oerlikon Italiana,** of Milan, are showing their completely redesigned model M4V vertical milling machine (Fig. 16).

In this modified version, a number of components has been redimensioned, including the vertical head, the column slides, the base, and the saddle supports. In addition, a new clamping system, controlled by hand-levers, for the table, the knee, the saddle, and the head

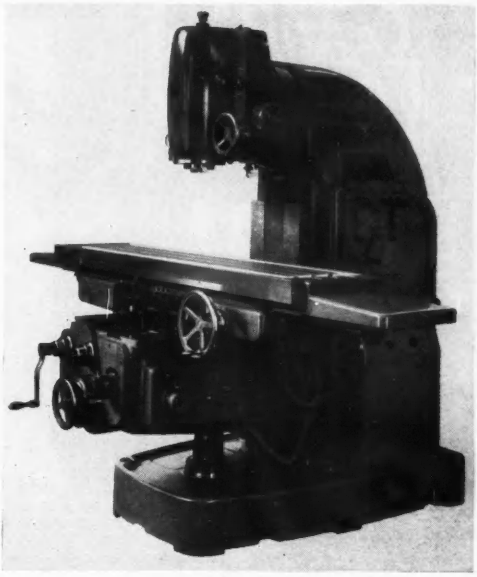


Fig. 16.

tough

Eclipse

TOOL BITS

Deep cuts on tough alloys call for extra stamina — tool bits that hold their edge under the most severe conditions — Eclipse tool bits, in fact.

It isn't only the extra high quality of steel used in their manufacture that gives ECLIPSE tool bits their outstanding qualities. The infinite care in manufacture, the modern plant where they are produced to rigid standards and the wealth of experience backing them — all contribute too.

***"Eclipse" tool bits are made from H-3 cobalt high speed steel in squares and rounds and as cutting-off tools and boring bars.**
The perfect companion to the ECLIPSE cobalt high speed steel tool bit is the ECLIPSE tool bit holder.
Ask for particulars of sizes and patterns.

Made by James Neill & Co. (Sheffield) Ltd. and obtainable from all tool distributors

UTS

has been incorporated. Other modifications include the provision of spindle and feed brakes, a backlash eliminator, and a graduated scale on both longitudinal and cross movements. If required, the machine can be supplied with an automatic cycle on the longitudinal, cross, and vertical traverses, a hydraulic knee-clamping device for the column, and a hydraulic copying attachment. The machine has a longitudinal automatic traverse of 1300 mm, the vertical traverse of the head being 160 mm.

In addition to their standard air-operated 150-kg hammer and a high-speed die-forging hammer with a 1250-mkg blow capacity, **Bêché & Grohs,** of Hückeswagen, Germany, are exhibiting their type LG.5 air-operated die-forging hammer with a tup weight of 200 kg. This hammer (Fig. 17) is electrically driven and is capable of effecting blows in rapid succession (up to 160 per minute).

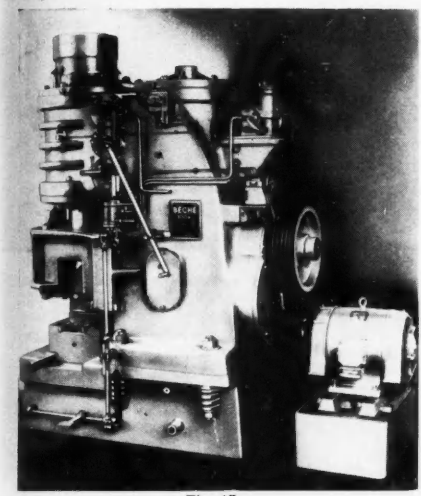


Fig. 17.

Operation is easily controlled by means of a pedal coupled with a servo-motor, and features include an accurate tup guide, a cast-steel anvil, and an exceptionally robust frame. This type of hammer is especially suitable for the production of small forgings requiring pre-rolling, bending, and die forging.

Exhibits from **Friedrich Deckel,** of Munich, cover a wide range of equipment, including universal tool milling machines, milling and boring machines, pantograph die-sinking machines, pantograph engraving and profiling milling machines, and grinding machines.

The K.F. 1 and K.F. 12 universal pantograph die-sinking machines have columns particularly well adapted to the requirements of die-sinking work in that the upper portion of the column extends over the work-table. The amply dimensioned column gap thus provided will accommodate bulky workpieces, long parts easily clearing the vertical portion of the column.

In the K.F. 1, the massive box-section column supports, by its lateral guide-ways, a vertically adjustable knee carrying a worktable which can be moved both lengthwise and crosswise. The copy-holder bracket, which is also provided with an elevating screw, is attached to the column at right angles to the knee. The copy-holder bracket carries the copy-holder table, which can be moved laterally. Both tables, whilst supported at approximately the same level, can be positioned individually.

In the K.F. 12 (Fig. 18), a vertically movable knee guided along the column face supports both the worktable and the copy-holder table, so that it is possible to

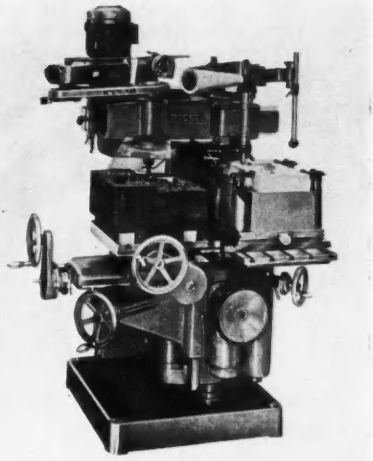


Fig. 18.

raise or lower the two tables simultaneously. The provision of a power elevating motor, which permits the knee to be moved at a rate of 30 ipm, affords a marked reduction in the time required for setting up or changing tools. By this means, it is possible to position heavy workpieces accurately. In addition, a large handwheel with a graduated drum has been provided for the purpose of vertical fine adjustment and infeed in the case of line-by-line milling operations. The three-dimensional pantograph is hinged to the upper end of the column and is connected with the tool slide through a slidably mounted universal joint.

Exhibits by **Heyligenstaedt,** of Giessen, Germany, include a new design of automatic copy-milling machine, model 170 FK6, which has a horizontal milling capacity of about 177 in., a vertical capacity of about 87 in., and a traverse of about 31 in. This machine is being shown demonstrating such operations as automatic milling in both horizontal and vertical directions ; contouring, using a model or template ; and contouring in layers with automatic transverse strips.

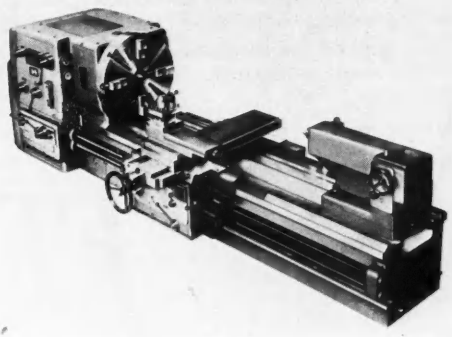
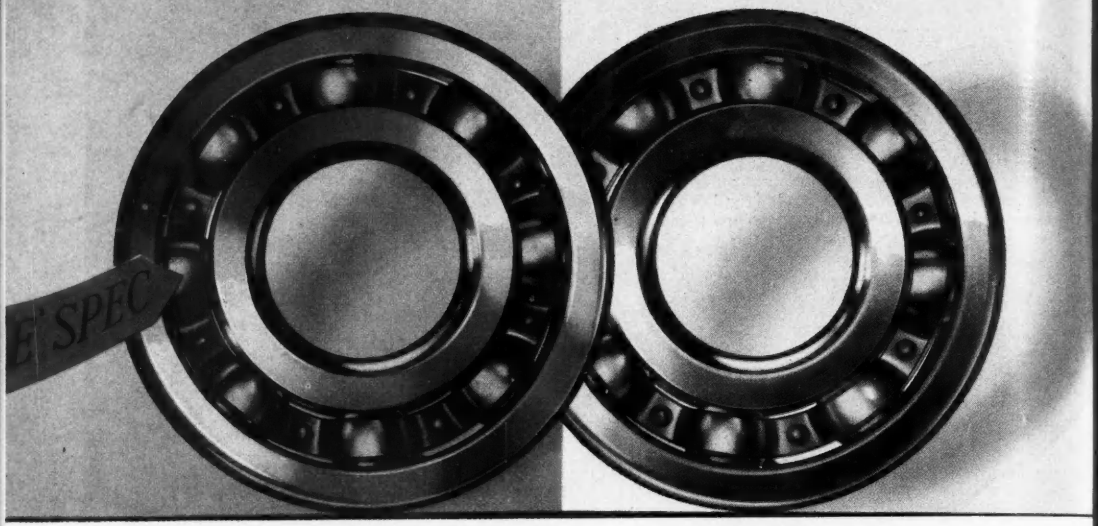


Fig. 19.

Other Heyligenstaedt exhibits cover a range of lathes, including a new design of heavy-duty lathe (Model 800 EN 4000), with a capacity of about 31 in. centre height and 157 in. centre distance ; a production copy lathe, model " Heycop " 1/1000 ; a model 6P facing lathe with a stepped-type cross-bed ; and the new model 450 E heavy-duty lathe. This machine (Fig. 19) has a capacity of about 18 in. centre height and about 157 in. centre distance,

PENNY PLAIN



TUPPENCE COLOURED

When you buy a standard article produced to a standard price, you may get good value but nothing out of the way.

For example, we make very good standard bearings at a normal price, but we also make bearings (to our 'E' specification) into which we put a great deal of extra know-how, workmanship and checking. They cost more of course, but what a difference!

They are meant for those who need the utmost life-and-death reliability; for those who have boosted up their original designs and are bottle-necked by standard bearings; and for those who need the quietest-running bearings.

The 'E spec' bearing—which isn't really coloured—is available in two forms, both dimensionally interchangeable with standard bearings: 'unsealed', and sealed with the FBC neoprene seal.

FBC

ALL-BRITISH
BALL AND PARALLEL-ROLLER BEARINGS

FISCHER BEARINGS COMPANY LIMITED, WOLVERHAMPTON

FISCHER BEARINGS COMPANY LTD. and TIMKEN-FISCHER STOCKISTS LTD., BIRMINGHAM
are both subsidiaries of BRITISH TIMKEN LTD.

F.B.C. :: FISCHER
Regd. Trade Marks

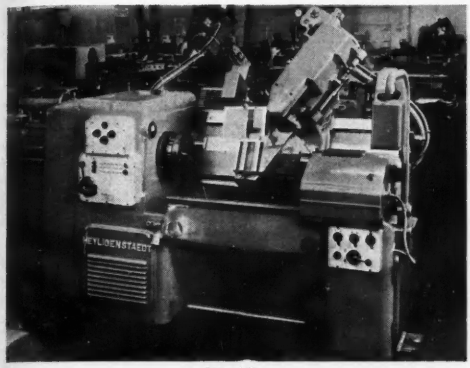


Fig. 20.

the maximum carrying capacity between centres without support being 9 tons. The headstock contains the reversing gear with automatic brake, acting as soon as the machine is stopped, and the gears for producing 18 working speeds. The machine can be stopped or reversed almost instantaneously, and spindle speeds are adjusted to a cutting-speed schedule by three conveniently arranged levers. The jaws of the large face-plate are reversible and move independently of each other.

Another interesting Heyligenstaedt exhibit is a newly designed " Heycomat " model 2 copying machine, with automatic loading device. In conjunction with the automatic cycle for automatic control of speeds, feeds, rapid traverse, and multi-cut control, this machine (Fig. 20) permits fully automatic machining of rough-forged and centered shafts by using a loading device. A transporting cap puts parts into the machine for chucking and machining, and a catcher takes out the finished parts. Controlling devices ensure an automatic cycle without danger to the machine or tool.

In addition to an indexing table machine for machining steering boxes, **Karl Hüller G.m.b.H.**, of Ludwigsburg, Germany, are exhibiting a fully automatic taper-roller grinding machine with a hopper feed, an automatic twin-spindle grinding machine for the surface-grinding of the inside of roller-bearing rings from 40 to 150 mm diameter in one loading, and two hydraulic vertical joint

Fig. 21.

spindle drilling machines, one with a stroke of 500 mm, and the other with a stroke of 350 mm.

Other Hüller exhibits include the FW5 and FS5 production milling machines. The FW5 has a 63 × 15¾ in. table, a longitudinal table traverse of 52 in., a cross traverse of 11 in., and a vertical traverse of 16 in., while the FS5 (Fig. 21) has a 51 × 14 in. table, and longitudinal cross, and vertical table traverses of 40, 12, and 16 in. respectively. In addition to their extensive milling traverse, these machines, which have good stock removal and are suitable for heavy cuts, have play compensation, a spindle brake, and a jump feed for an automatic work cycle.

The most important development shown by **Schaudt Maschinenbau G.m.b.H.**, of Stuttgart, is a range of three entirely new cylindrical grinding machines, designated respectively the PRS, ARS, and ERS. The largest of these is model PRS, with a grinding-wheel diameter of 29½ in., and a normal centre height of 9⅞ in. Four sizes of this particular model are available, with centre distances ranging from 19⅝ to 78¾ in.

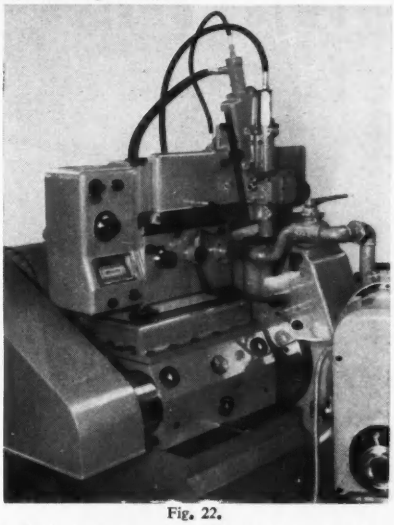


Fig. 22.

The hydraulic system of this range of machines has been arranged so that it is at the rear of the machine, rather than in the base casting. Maintenance is thus greatly simplified, since oil can be changed without leaving residual used oil in the tank. All controls are conveniently grouped on a compact control panel, the conventional single-lever control having been superseded by a push-button as a safety measure. The feed handwheel for the grinding wheel is located on the right side of the control panel, the infeed position in relation to the table being capable of variation. The feed may be finely adjusted to units as small as 0·00004 in. and, during plunge-grinding, a continuous feed system is employed. A variable spark-out control is fitted for use during trip-stop grinding, and the wheelhead is carried on roller tracks to enable full advantage to be taken of the inherent sensitivity of the machine. A sizing control unit can be supplied as extra equipment, as can an internal grinding attachment and a form grinding attachment.

The newly introduced form-dressing attachment for the S-type machines is of particular value for plunge-cut grinding large- or medium-size batches of work. A tracer enables the profiles of a template to be transmitted to the grinding wheel through a dressing diamond. This operation is fully automatic, since the hydraulically actuated dressing quill travels across the wheel, lifts, and returns to its starting point. The attachment can be adjusted so

'TRUSHANK'

'DOUBLE MUSHET' HIGH SPEED STEEL TWIST DRILLS

Famous drills improved . . .

The best of two worlds is combined in "TRUSHANK"—the latest refinement to the famous range of "Mushet" brands high-speed steel twist drills.

The bright taper shank is precision ground to ensure an accurate fit in the socket, whilst the body of the drill, with its distinctive blue-black oxide coating retains all the many advantages of steam temper—additional toughness, stress freedom, corrosion resistance, etc.

Order "TRUSHANK" now and prove their greater efficiency during a longer and trouble-free life. They cost no more.

A TROUBLE FREE SHANK

ON A STEAM TEMPER DRILL

OSBORN

SAMUEL OSBORN & CO., LIMITED
CLYDE STEEL WORKS, SHEFFIELD

that the diamond advances towards the grinding wheel by a predetermined amount at each traverse. A special device permits the wheel to be dressed after a number of components has been ground. A further mechanism determines the number of times the wheel is to be dressed, a coloured lamp indicating that dressing is in progress and that the feed cannot be engaged. Apart from its value in speeding up production, the form-dressing attachment enables a close watch to be kept on the wear of the wheel in relation to work performed on the component, and on the general maintenance of grinding wheels. Fig. 22 shows the form-dressing attachment mounted on the PRS cylindrical grinder.

Exhibits from **Schiess,** of Dusseldorf, cover a range of their heavier machine tools, including single-column vertical turret lathes, a double-column vertical boring mill, and a horizontal milling and boring machine.

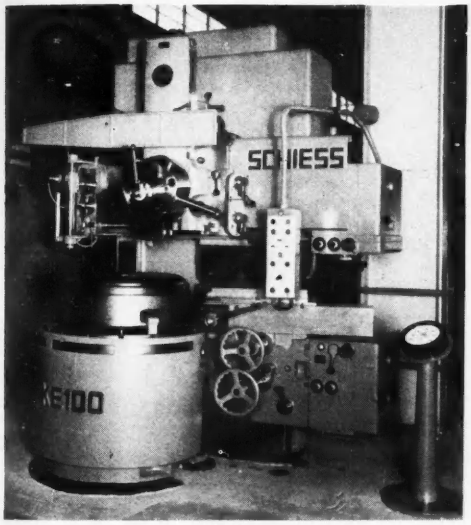


Fig. 23.

An example of one of their single-column vertical turret lathes, the model KE 100, is shown in Fig. 23. Equipped with side-head, taper-turning, and screw-cutting attachments, and with automatically operating speed control, this machine has a maximum turning diameter with the side head down of about 45¼ in., a maximum turning height over the table of about 45½ in., and a permissible table load of 3 tons.

An interesting exhibit by **Pee-Wee Maschinen G.m.b.H.,** of Berlin, is their model A.S.R. stud-making machine, by means of which studs are produced from coiled wire of 70-tsi tensile strength.

This machine (Fig. 24) is fully automatic in operation. The coiled wire is automatically picked up by a clamping slide guide, from which it is drawn through a straightening attachment and a drawing bush which sizes the wire up to 3% cross-section reduction. At the end of its travel, the wire is cut to length by shearing bushes. The ends of the blanks to be threaded are then reduced to the pre-rolling dimensions of the thread, after which they are chamfered, and finally the threads are rolled on each end of the stud.

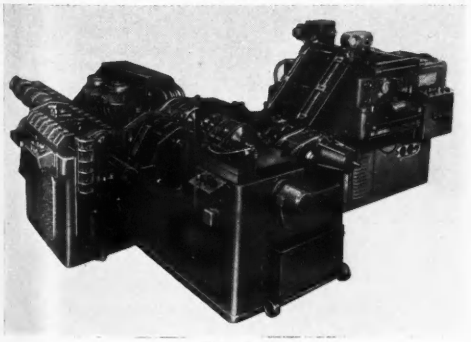


Fig. 24.

Exhibits from **George Swift & Sons Limited,** of Halifax, include their 12.SV.6 lathe (Fig. 25), which is a straight-bed, roller-bearing spindle, all-geared headstock surfacing and boring lathe on an inverted-vee bed, 8 ft 6 in. in length, to admit 2 ft 6 in. between the chuck and the turret. Eighteen changes of speed are provided in the

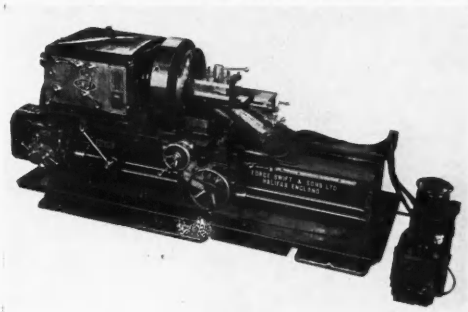


Fig. 25.

headstock, which is driven through a Beier variable-speed box controlled from the traverse of the surface slide to give constant cutting speed. Nine changes of feed are provided, giving sliding feeds of from 25 to 282 cpi and surfacing feeds of 66 to 740 cpi.

The four-way turret is mounted on hydraulic copying slides, providing copy-forming motion to the surfacing slide. By means of the " Swift " special copying arrangement, the complete form of a surface can be copied at one setting. The machine is driven by a 12½-hp motor with a reversing starter, and a rapid power traverse to the surfacing motion is also fitted.

In addition to a multiple rotary gang-slitter, **Officine Meccaniche Romildo Mariani,** of Milan, Italy, are exhibiting the Mariani flying shears (Fig. 26), which permit automatic cutting of sections produced by cold-roll-forming machines. In this machine, the body of which is of rigid, ribbed box-type construction, motion is transmitted by an electric motor to a flywheel rotating freely on the shaft of the eccentric, which, in turn, rotates on

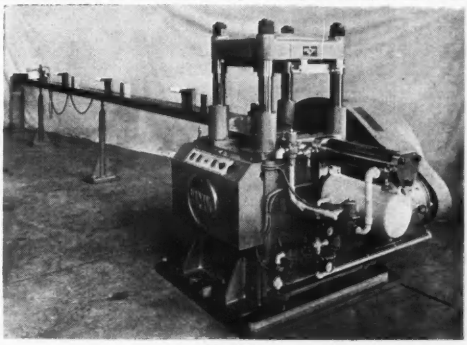
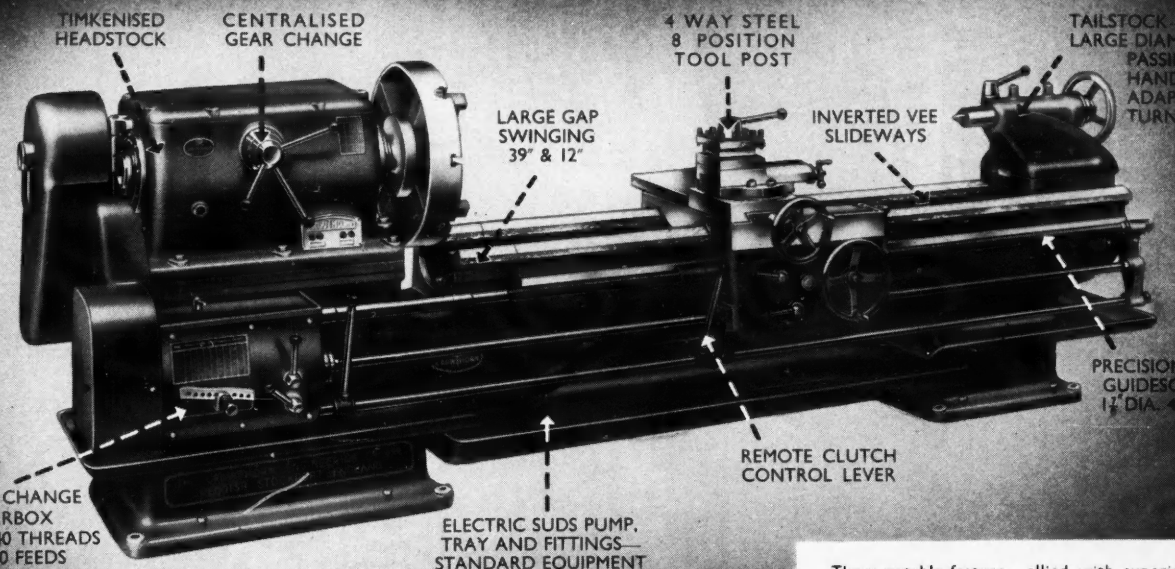


Fig. 26.

12½" heavy duty CENTRE LATHE


TIMKENISED HEADSTOCK
CENTRALISED GEAR CHANGE
4 WAY STEEL 8 POSITION TOOL POST
TAILSTOCK— LARGE DIAMETER BARREL PASSING THROUGH HANDWHEEL ADAPTABLE FOR TURNING TAPER
LARGE GAP SWINGING 39" & 12"
INVERTED VEE SLIDEWAYS
PRECISION CUT GUIDESCREW 1½" DIA. 4 T.P.I.
QUICK CHANGE GEARBOX GIVING 40 THREADS AND 40 FEEDS
ELECTRIC SUDS PUMP, TRAY AND FITTINGS— STANDARD EQUIPMENT
REMOTE CLUTCH CONTROL LEVER

These notable features, allied with superior quality in every stage of design and manufacture have made Crowthorn lathes famous for high speed precision work under exacting conditions.
Reasonable delivery times.
Please write for illustrated literature.

CROWTHORN
HIGH CLASS MACHINE TOOL MAKERS

CROWTHORN ENGINEERING COMPANY LIMITED
REDDISH · STOCKPORT · ENGLAND
Phone: STOCKPORT 2067-8 *Grams: CROWTOOL, REDDISH*

special slides and, through four rugged special steel columns, transmits a vertical motion to the upper toolholder. This vertical motion is controlled by an electro-pneumatic servo-control and permits the tool to have, during cutting, the same speed as the section coming from the cold-roll-forming machine. Consequently, the cut is the result of two simultaneous movements, one vertical and the other horizontal. A special device ensures that the machine operates at the right pressure only. Thus, if the pressure is insufficient, motion of the forming machine is immediately stopped. A switch on the control panel automatically synchronizes the shears with the feed from the forming machine.

Among other items, exhibits from **Wadkin Ltd.**, of Leicester, are two heavy-duty radial routers, demonstrating alternative methods of carrying the router head. On the larger machine, type H.Y.R.5 (Fig. 27), the radial arm is a substantial one-piece box-section aluminium casting mounted on sixteen dustproof rollers operating on nitralloy bars secured to the arm. The arm and its mounting are designed to avoid all possibility of deflection or distortion and to maintain accuracy in relation to the table surface at all positions. The arm has an effective radius of 6 ft 1 in. maximum and 2 ft 9 in. minimum, and is mounted in a roller carriage carried on a rotating barrel, which, in turn, is mounted in a heavy main frame. The barrel bearing design is such that the bearings are heavily preloaded to give absolute accuracy in the sweep of the arm. The complete routing machine unit is mounted on a bed and is power-traversed at a rate of 10 fpm over a heavy-section cast-iron table having a working surface of 12 ft 8 in. × 2 ft 6 in. The machine is designed for operating with the template fitted to the workpiece, but an overhead tracer pin is fitted, so that, if required, the machine can operate from templates carried in a structure overhead. If required, the routing unit can be supplied as a fixed machine operating over a plain, fixed, or rising and falling table.

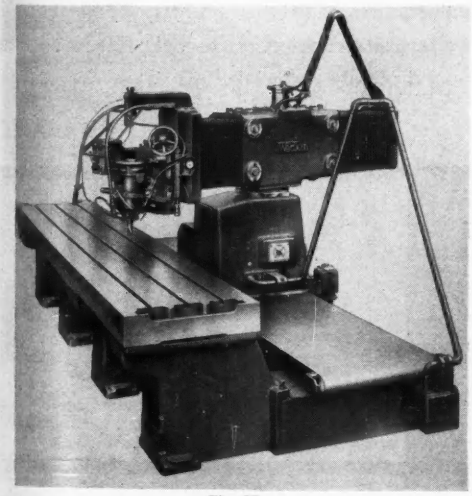


Fig. 27.

The other heavy-duty router is of the articulated-arm type. The arm in this case is in two parts, both of very deep section and hinged on large heavy-duty ball races. Motion of the arm is different from that of the straight-arm radial type, which sweeps over an area, whilst the articulated arm has a knee action, its movement being smooth and easily controlled.

In addition to their model MNu 360 high-speed notching press, which is capable of 1000 strokes per minute, **L. Schuler AG**, of Goeppingen, Germany, are

Fig. 28.

exhibiting a wide range of their presses, including a 50-ton high-speed die press, a 125-ton high-speed press, a 315-ton wide-frame double-sided power press with cross-shaft drive, a new design of 325-ton "Hydrovit" hydraulic drawing press, a 100-ton knuckle-joint embossing press, a 50-ton inclinable double-sided C-frame press, and a 63-ton geared double-sided C-frame press, both these C-frame presses being equipped with the Schuler electromagnetically operated friction clutch and brake unit and electrical control system, which is designed to ensure an exceptional degree of safety.

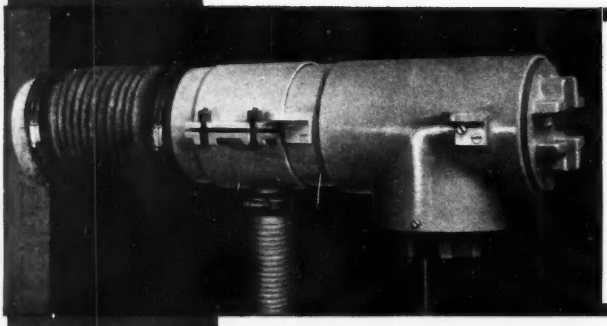
Another Schuler exhibit is the 300-ton, 9-station transfer press, model PStw 300/9/350, shown in Fig. 28. Designed for the economical mass production of pressed and drawn components, this type of press incorporates a number of special features. Thus, for example, the entire pressure exerted is absorbed by the press frame, i.e., the loading on the anchor columns is purely tensile. In addition, four long adjustable guides for the ram are fitted in each upright, and transverse stresses on the ram guides are kept to a minimum. Also, adverse effects caused by uneven load distribution are kept to a minimum, complete accessibility to tools on all sides is provided, and complete safety of operation is ensured.

The principal feature of exhibits from **E.M.I. Electronics Ltd.**, of Hayes, Middlesex, is the application of numerical control to a Cincinnati "Hydrotel" vertical milling machine, in which the motions of the machine are controlled in all three dimensions. The vertical movement of the cutter spindle and the longitudinal and lateral traverses of the work-table slide are each equipped with servo-controls and position-identifying mechanisms, and the master control incorporates two interpolator units. These can be applied to any of the machine motions to give continuous parabolic interpolation, while the motion of the third dimension is controlled at selected discrete points.

The longitudinal, lateral, and vertical co-ordinates of the workpiece are set out sequentially in tabular form and are then typed on a teletypewriter, which produces a punched paper tape in five-digit decimal binary code, together with a typed sheet for checking. The tape is fed into the control unit, where the coded figures are retained by the information store until they are no longer required. Analogue circuits interpolate the necessary

SILICONES AND SMOKE SIGNALS

I.C.I. Silicone Rubbers have a knack of solving many a tricky problem. To observe smoke density aboard certain H.M. warships, special photo-electric equipment, designed and manufactured by Radiovisor Parent Limited, has been installed. The viewing unit of the equipment is connected to the smoke ducting by a flexible hose of I.C.I. Silicone Rubber which isolates the instrument from any shipboard vibration. Another hose supplies purging air to the glasses of the projector and receiver to keep them free from soot deposits. The flexibility of I.C.I. Silicone Rubbers is maintained even at elevated temperatures, and this property combines with chemical resistance and excellent electrical characteristics to make these elastomers some of today's most interesting—and useful—materials.



I.C.I.

SILICONE RUBBERS

—material progress

For fullest information get in touch with

IMPERIAL CHEMICAL INDUSTRIES LTD., LONDON, S.W.1.

ICI

NS 44

additional information to cause the machine tool to cut a smooth curve. Interpolation can be carried out on signals controlling the motions of any two selected axes. Motion along the third axis can be continuous or discontinuous, as required.

In the "Hydrotel" the various slide motions are operated by hydraulic rams, the link between the data control and the hydraulic system being electro-hydraulic-valves. The voltages produced from the analogue circuits and the voltages fed back from the position-identifying units fitted on each of the slide motions are compared, the resultant error voltage being amplified and determining the amount of displacement of the hydraulic servo-valves. The accuracy of the information given to the machine tool by the control system is better than 0·0003 in. Once the paper tape has been fed into the control system, the machine tool operates entirely automatically. The system therefore has all the advantages of a copying machine, without the cost and labour of making templates, so that short runs or prototype parts can be produced as cheaply as longer runs. In addition, it is ideal for the production of master cams and templates for use on conventional copying machines.

Among a wide range of equipment, including automatic single-spindle chucking machines and screw machines, automatic bar machines, and the redesigned form of their 6-in. hydraulic copy-turning lathe, **B.S.A. Tools Limited,** of Kitts Green, Birmingham, are exhibiting their B.S.A. No. 4 centreless grinding machine, which, in this instance, is equipped to grind an armature shaft component on four stepped diameters. With this machine (Fig. 29) the production cycle is completely automatic, the components being ground by the infeed method. The infeed attachment is arranged to run continuously during production, so that one revolution of the infeed cam represents the full cycle time for producing each component.

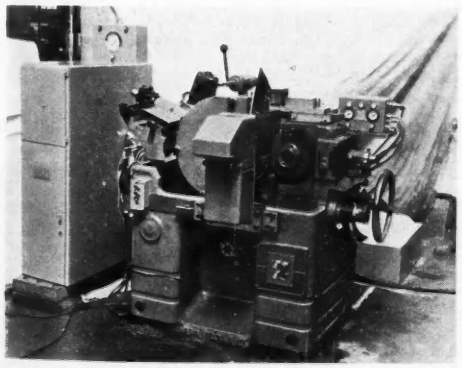


Fig. 29.

The workpieces are fed from a vertical-type magazine into an automatic synchronized leading attachment which is controlled to operate at the correct moment in the cycle by a pilot air-valve operated from a cam on the infeed attachment. This valve initiates the return of the overhead carriage, which at the conclusion of the grinding operation conveys the component from the wheel area onto a size-gauging block positioned on a cross-slide, and, at the same time, the previously ground component is ejected from the gauge-block into the delivery tray provided. The cross-slide then advances to the loading position with a new component from the magazine, and the overhead carriage conveys this workpiece to the grinding position between the wheels. The cross-slide returns during the grinding operation to accept the next component from the magazine.

The machine is also fitted with automatic sizing and grinding-wheel-head feed compensation, by means of which each component after grinding is automatically sized, and any growth towards the upper limit of the tolerance band is registered in the "Sigmatrol" unit, causing the grinding-wheel head to advance automatically and bring the component size towards the lower limit of the tolerance band. This means that the machine is automatically controlled to produce continuously workpieces within the allowable tolerance. The actual sizing of the ground piece on the gauge-block positioned on the cross-slide takes place during the spark-out period of the grinding operation. The sizing period is determined by a switch operated from a cam mounted on the infeed cam spindle. If for any reason components are produced which fall below the lower limit of the tolerance, a minus alarm signal will be given and the machine cycle will be arrested.

A modern roller shearing machine for cutting long metal plates is being exhibited by **Schulze & Naumann,** of Essen. Weighing 70 tons and operated by a 150-hp motor, this machine (Fig. 30) has a shearing capacity of $\frac{7}{8}$ in. × 40 ft and a planing capacity of 2 in. × 40 ft.

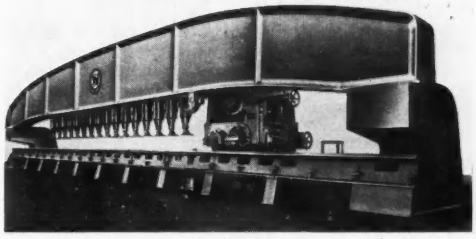


Fig. 30.

This machine is mainly used in the shipbuilding industry, and also for boilermaking, locomotive and carriage building, tank making, and the production of welded tubes. The accuracy of this unit is stated to be such that, if two plates are butted together after cutting, the maximum gap over a length of 25 ft is 0·004 in., or 0·008 in. over a length of 40 ft. Although the shearing cuts are of excellent quality, the machine is provided with an additional high-duty planing attachment of ample dimensions for machining special edges. Various items of special equipment are also available, by means of which it is possible to load and unload the plates very rapidly, thus increasing efficiency and reducing handling times to a minimum.

Included in the wide range of exhibits by **James Neill & Company (Sheffield) Limited,** of Sheffield, are examples of rectangular models of their "Eclipse" permanent-magnet chucks, ranging from the 5 × 2½ in. minor chuck for toolmakers to 18 × 12 in. heavy-duty chucks. In addition, there is a selection of circular lathe chucks, ranging from 4¾ to 12 in. in diameter, together with a comprehensive range of accessories for magnetic chucks, including chuck blocks for accommodating pieces with projections, adaptor plates, swivelling brackets for use with rectangular chucks, and "Eclipse" demagnetizers.

Other "Eclipse" exhibits cover a range of versatile magnetic tools, including magnetic links, hand magnets, magnetic holders for cylindrical or flat work during welding or other operations, and magnetic bases for dial gauges, of which the heavier model (No. 901B) is being shown for the first time.

Supporting these exhibits is a comprehensive variety of "Eclipse" tools, including hacksaw blades and frames, tool bits and tool-bit holders, cutting-off tools and holders, lathe-tool sets, and the "Eclipse" No. 55 sheet saw, which is designed to cut sheet material of all types, plain or corrugated, and which uses a standard type of hacksaw blade capable of being varied in pitch to suit different materials being cut.

HANOVER EXHIBITION

SEPTEMBER 15th–24th 1957

HALL 9, STAND No. 9424

ROCH-ETALON

PRECISION MEASURING INSTRUMENTS : ● VERNIER CALIPERS WITH THE NEW MATT-CHROME FINISH ● 'INGAGE' DIRECT READING INTERNAL MICROMETERS ● DIAL TEST INDICATORS ● MICROMETERS.

HALL 9, STAND No. 9308

FRIEDR SCHULER

COMPLETE RANGE OF :—SLITTING SAWS & MILLING CUTTERS FOR EVERY APPLICATION.

HALL 9, STAND No. 9406

ROHM

● DRILL CHUCKS ● QUICK ACTION VICE ● LATHE CENTRES featuring the new automatic tailstock centre with pressure gauge.

HALL 9, STAND No. 9615

HARTWERKZEUG

SOLID TUNGSTEN CARBIDE : ● CIRCULAR SAWS ● DRILLS ● BURRS ● COUNTERSINKS ● FILES ● MICA-UNDERCUTTERS ● REAMERS ● END-MILLS.

Sole importers in the United Kingdom

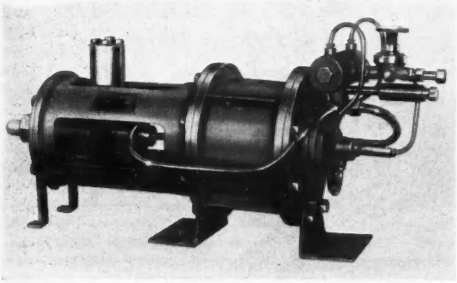
ALEXANDER S. NEWALL, MACHINE TOOL COMPANY LIMITED

287 FINCHLEY ROAD, LONDON N.W.3 Tel: HAMPSTEAD LONDON 3855/9949 Telegrams: ETALON LONDON

British Industrial Developments

Air-Operated Hydraulic Pump

The maximum possible pressure of the " Airhydropump " produced by Charles S. Madan & Co. Ltd., of Broadheath, Altrincham, has now, in the latest model, been increased from 27,000 to no less than 55,000 psi. In order to be able to handle this extremely high pressure, it was necessary to design a complete range of suitable hydraulic control valves, pressure-release valves, and non-return valves, together with a series of pipeline couplings, tee-pieces, and other fittings.



This compressed-air-operated hydraulic pump has a theoretical air/hydraulic pressure ratio of 1 : 694, and is capable of generating pressures between 25,000 and 55,000 psi when powered by a normal shop air-line up to 100 psi. It is particularly suitable for testing in the above pressure range, and for many manufacturing processes in the steel, chemical, and allied industries. Measuring only $12\frac{1}{2} \times 44 \times 18$ in. high, the unit is portable and compact, and is fully automatic in operation, while the special air reducing valve fitted enables any intermediate hydraulic pressure to be obtained easily.

This new version of the " Airhydropump " is also available as a mobile unit, mounted on a four-wheel trolley with jack-type steering, rubber tyres, and a 5-gal reservoir. Additional equipment for this version includes special stop and release valves, a 10-in. dial pressure-gauge graduated to 70,000 psi, air and hydraulic filters, and associated piping.

Adsorption Dryers for Nuclear Power Stations

In addition to a batch of eight special twin-pot furnaces for the Industrial Group Headquarters of the Atomic Energy Authority, Birlec Limited, of Erdington, Birmingham, announce that they have received orders for air- and gas-drying equipment for three nuclear power stations, i.e., at Dounreay and Berkeley, and in the south of Scotland.

For the experimental power project at Dounreay, Birlec are to supply air-drying plant for the fast-reactor sphere, for which an alloy of sodium and potassium is used as the heat-transfer medium. This dryer, which will remove more than 30,000 grains of moisture per hour at temperatures up to 90°F, will initially be required to dry the whole volume of 1,030,000 cu ft of air in the sphere. The moisture content of 86 grains per pound must be reduced to 12 grains per pound within a period of 14 days. When the space has been conditioned, the moisture content will be maintained at the latter figure by removing the 30,000 grains per hour evolved, and also the moisture evolved in the CO_2 adsorption plant. This entails moisture removal even when the relative humidity is as low as 5%, as would be the case when the dry-bulb temperature rises to 90°F. Furthermore, while the equipment must be capable of dealing with this work, its size and weight are limited. The desiccant vessels must be small enough to pass through access doors only 7 ft wide by 9 ft high, and no vessel may exceed 5 tons gross weight when complete and filled with alumina.

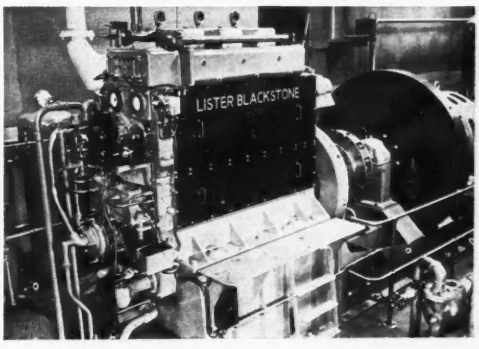
For the Berkeley station, Birlec are to supply eight adsorption dryers and dual heat exchangers, four dryers to operate continuously with each reactor. Their purpose is to prevent condensation and consequent corrosion taking place in any part of the carefully prepared CO_2 gas system. Each dryer will receive 115 cu ft per minute of saturated gas, removing 1·25 lb of moisture per hour. Should a steam coil burst, the system can be returned to the required dryness within 12 to 14 hours. This type of adsorption dryer consists basically of two cylindrical chambers filled with moisture-adsorbent material, which are interconnected by valves so that, while gas is being dried in one, the other may be reactivated by means of a built-in heater. Thus, with automatic change-over valves, continuous drying is obtained.

Four similar dryers are to be supplied for the South of Scotland station, where they will deal with a charge of 100 tons of CO_2. Each unit will remove continuously a maximum of over 4·2 lb of moisture from a gas flow of 10,200 lb per hour. The moisture content of the original charge will be dried from 0·05% by weight to 0·03% in less than 24 hours, and must be returned to the latter figure promptly after the addition of 1 ton of CO_2 at 0·05% once a day.

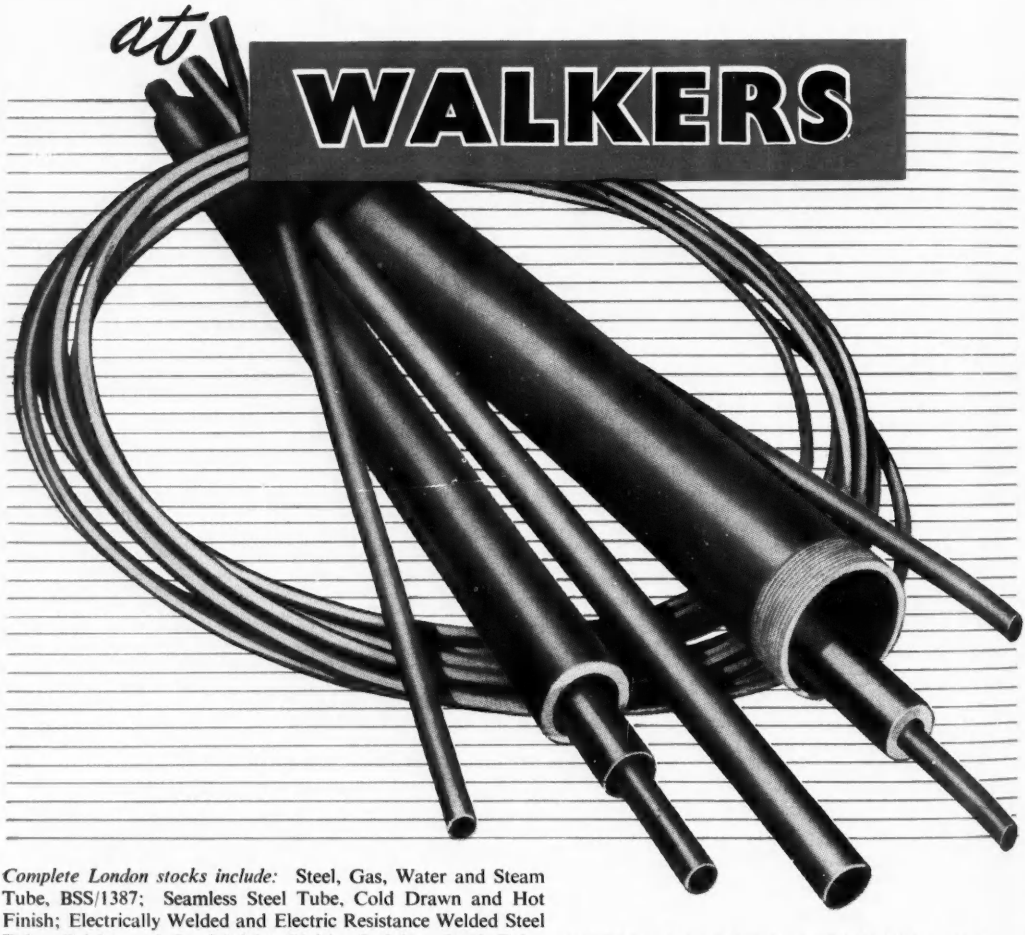
" No-Break " Stand-by Alternator Sets

A new range of " no-break " alternator sets, of from 85 to 380 kW output and operated at engine speeds of 600 and 700 rpm, has been developed at the Stamford (Lincolnshire) works of the Lister-Blackstone Group. These sets are specifically intended to meet present-day requirements of atomic-power generation, telecommunications, radar, and similar electronic circuits, and in the continuous-process industries, all of which demand a constant source of electrical energy without temporary shut-down losses.

Stand-by power for such installations must be capable of taking over duty without a break. For this purpose, the " no-break " set includes an independent flywheel of substantial diameter and weight, motored by the alternator when mains supply is available. On mains failure, the considerable momentum of the flywheel is sufficient not only to start the stand-by diesel engine but also to drive the alternator and to maintain electrical output in



You won't often see a *FLUSH* OF MALLARDS, or a *CHARM* OF FINCHES, or a *COVEY* OF PARTRIDGES but you'll always find a MULTITUDE OF TUBES at WALKERS



Complete London stocks include: Steel, Gas, Water and Steam Tube, BSS/1387; Seamless Steel Tube, Cold Drawn and Hot Finish; Electrically Welded and Electric Resistance Welded Steel Tube, Bright and Semi-Bright Finish; Stainless Steel Tube, Seamless and Welded; Brass Tube, Seamless and Welded; Copper Tube for Domestic Water Services BSS 659/1944; Copper Tube for Underground Services BSS 1386/1947; Copper Tube for all Commercial Services; Conduit Steel Tube, Welded and Solid Drawn; Aluminium Tube, also all applicable FITTINGS.

M. W. WALKER & STAFF LTD
ENGINEERS' MERCHANTS
IBEX HOUSE, MINORIES, LONDON, E.C.3
'Phone: ROYal 8191 (10 lines) 'Grams: Makerlaw, Fen, London
MIDDLE EAST BRANCH—KUWAIT—PERSIAN GULF

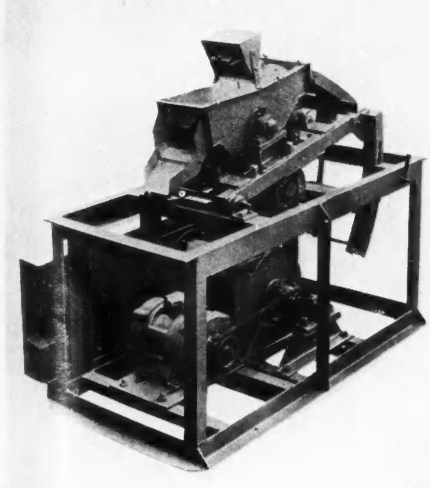
the circuit until the engine takes over this duty. Thus, for example, in the 85-kW set illustrated, the flywheel is 5 ft 9 in. in diameter and, with the shaft assembly, weighs about 4 tons. The flywheel is coupled to the driven shaft through an air-operated friction clutch, a Lister-Blackstone flexible coupling and nodal damper being installed between this clutch and the flywheel. This unit effectively absorbs any harmful torsional vibrations in the shafting. The assembly is carried on two pedestal bearings, the bearing nearest the generator being constructed to house a gear-driven lubricating-oil pump which supplies the engine and these bearings whenever the flywheel is running. Alarms are fitted to give warning of any possible excess of temperature in the bearings and lubricating system.

Control equipment for the engine and clutch comprises a servo-reset, spring-controlled, electrically tripped fuel shut-off, operating directly on the pump rack spindle ; two balanced three-way electromagnetic air valves ; and two pneumatic rams connected to the clutch engagement mechanism. This control equipment is associated with a circuit-breaker with double-pole auxiliary contacts, giving it quick opening characteristics on reverse current flow.

Vibrating Pneumatic Jigs

Designed for the dry separation and recovery of material in size ranges between ½-in. cube and 10-mesh BSS, the range of " Vibrair " jigs produced by Knapp & Bates Ltd., of London, W.C.2, operates on dry material and is particularly effective when scalping low-grade material to produce a clean tailing. As such, these jigs are particularly suitable for such applications as the elimination of barren waste in grinding circuits, the preparation of high-grade non-metallic minerals, and the recovery of valuable material from industrial wastes.

Construction and operation of these machines are simple, the basic principle involved being that of an air cushion created above a vibrating, inclined plate. Owing to specific-gravity differences in the material being treated, light particles, which are more easily airborne, are carried down the plate, while heavy particles ride up the plate, because of their more frequent contact with the vibratory motion. The machine consists of a sloping trough, coupled to a windbox which receives air from a fan. The air emerges from the windbox through a porous, sintered phosphor-bronze plate which forms the trough bed. Vibration of the trough is effected by a high-speed, low-amplitude eccentric, this motion being controlled by varying the speed of the eccentric and by adjusting four toggles which hold the trough in position. A control for the fan motor is included, to provide regulation of the air volume passing through the sintered plate.



In operation, a hopper feeds material to the trough, a variable hopper aperture and a vibrating feeder being fitted to ensure even rate of feed. As the particles fall onto the porous plate, they are affected by the current of uprising air and the vibratory motion of the trough, a " pool " of heavy material forming behind a weir at the lower end. As soon as this pool has been formed, additional heavy material is carried up the slope of the trough, whilst lighter material rides over the pool and is discharged at the lower end.

The capacities of these jigs vary according to the type of material being treated, and for the three units now being produced are from 100 to 200 lb/hr, 500 to 800 lb/hr, and 1000 to 1500 lb/hr respectively.

Surge-Injector Welding Units

Two new models of the " Saturn-Hivolt " surge-injector argon-arc welding unit, Mk. II and Mk. III, are announced by Saturn Industrial Gases Ltd., of Southall, Middlesex. These units have been developed directly from the Mk. I machine but, among other improvements, have a built-in transformer, giving complete mobility to the whole unit, which is mounted on castors and is very compact.

These new machines for welding aluminium, aluminium alloys, and stainless steel have a current range of 30 to 600 A from a 42-V open-circuit a.c. supply, giving the operator complete safety from shock and a very wide scope for welding, all the more so because automatic control of water and argon leaves him entirely free to concentrate on welding. The surge-injector unit is fitted with an auxiliary device which feeds a higher-voltage spark to strike the initial arc and, as soon as the arc is struck, the high-voltage pulse is automatically switched off and the low-voltage surge maintains the arc.

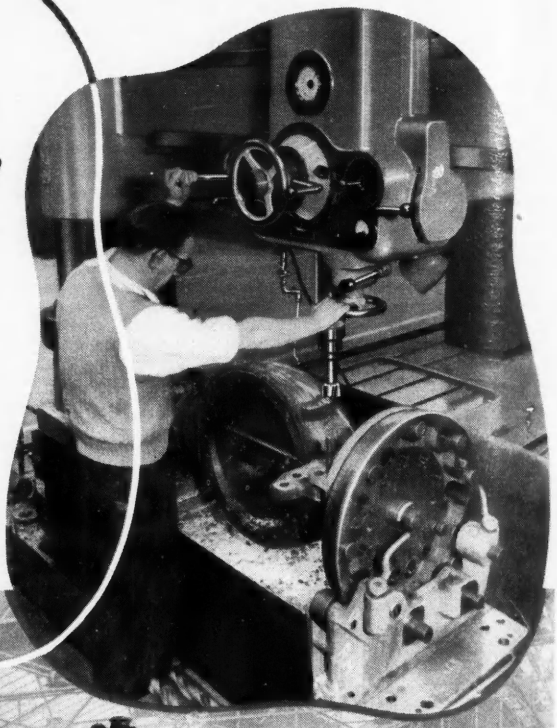
Adhesive Stopping-off Tapes for Plating Processes

A range of seven types of " Speedfix " self-adhesive stopping-off tapes for use in plating processes has been developed by Industrial Tapes Ltd., of London, E.C.1. With the aid of these tapes, stopping-off is reduced to a simple procedure of winding a suitable tape around the area to be masked, and then stripping it on completion of the plating process. Bearing in mind the fundamental requirements for suitability in plating operations, these tapes have been specially developed to be resistant to acids, alkaline solutions, and temperatures up to boiling point. In addition, they combine freedom from chemical

"Greater operating speeds"

. . . . say 'EUCLID'

Archdale mechanical and hydraulic "Pre-selects" with special indexing fixtures are used by Euclid (Great Britain) Ltd., to ensure the efficient drilling tapping and spot facing of the many holes in these heavy duty rear axle casings. These machines give 22 spindle speeds and 18 rates of feed, all pre-selected at any time with the spindle stationary or running. Capacity: 3½" dia., in M.S. Speeds: 11 to 1450 rpm. Feeds: 8 to 540 rpi. Built in sizes from 5 ft to 12 ft spindle radius.



ARCHDALE "pre-select" RADIALS

JAMES ARCHDALE & CO. LTD., LEDSAM ST., BIRMINGHAM 16

SOLE AGENTS: ALFRED HERBERT LTD., COVENTRY

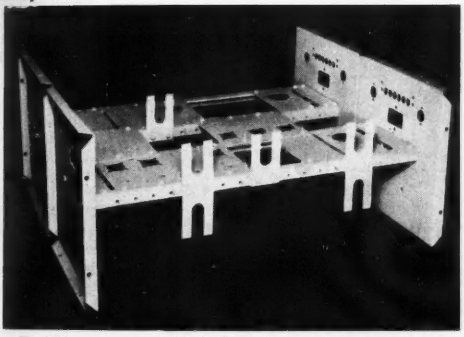
A member of the Staveley Coal & Iron Co. Ltd.

reaction between the adhesive and the metal surface, and freedom from deposit when the adhesive tape is stripped away, with extreme flexibility, rendering them suitable for stopping-off uneven surfaces, grooves, slots, etc.

These tapes may sometimes be used in conjunction with conventional wax dipping, in order to obtain an absolutely straight edge on an otherwise entirely wax-covered unit. For this purpose, some of the tapes are available in various colours, so that the edge can clearly be seen through the wax coating. For convenient application, a special slicing dispenser is available, enabling the tape to be cut in any width from 0·1 up to 2 in.

Laboratory Chassis Kit for Development of Electronic Equipment

Designed to replace the various temporary chassis, panels, etc. required for fabrication during the development of electronic equipment, the " Standard Chassis " kit produced by Cowell Developments, of London, W.3, is a versatile laboratory metalwork system which permits the rapid assembly from a small number of standard parts of a chassis appropriate to a particular circuit requirement. Furthermore, the design is mechanically robust and permits ease of component changing, voltage checking, etc., while the position of all parts mounted on the chassis can be altered at will. Any number of unit chassis (each capable of accepting up to eight valves, etc.) may be joined together for large layouts or for extending chassis already in use, and units or groups of units can conveniently be fixed directly to standard rack panels.



Facilities are provided for plug-and-socket power-supply connections, together with simple arrangements for switching and metering. If special components have to be mounted (e.g., screened connectors and transformers), it is a simple matter to cut blank plates to accept these units, and after use to return them to stock, together with the other components of the chassis. The chassis is constructed of cadmium-plated mild steel and is available in unit-kit form, comprising 2 end-plates, 2 brackets, 2 runners, 6 small valve-holder plates, 3 large valve-holder plates, 6 potentiometer brackets, 3 large blank plates, 3 small blank plates, and a supply of screws, etc.

Continuously Cast Iron Tubes

As a result of their experience over the past ten years in the production of " Flocast " continuously cast iron bar, Harold Andrews Sheepbridge Ltd., of Halesowen, Birmingham, announce the successful completion of the more difficult task of continuously casting iron in tubular form.

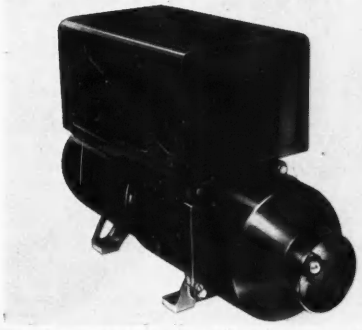
Like " Flocast " iron bar, " Flocast " iron tube is manufactured under rigid metallurgical control and is a continuously cast product formed in a special die held at constant temperature, being withdrawn rapidly and uniformly by an electronically controlled mechanism. The tube is made from a standard grey iron of very close grain structure, with extremely fine nucleiform graphite, giving high strength and wear properties, and with binary phosphide present in a general " honeycomb " network, the phosphorus content being held between 0·40 and 0·60%. An alternative material, designated H2, is also available, containing in addition 0·50% chromium and 1·0 to 1·5% nickel, this material being primarily suitable for heat treatment where a Brinell hardness of 400 to 450 is required. The standard material has an as-cast Brinell hardness of 200 to 230, with a small variation in hardness between the bore and outside diameter. Tensile strength ranges between 13 and 16 tsi, with a slight increase in the case of the as-cast H2.

These tubes are guaranteed sound throughout their length, being entirely free from blowholes, inclusions, and porosity. They are available in the as-cast condition, or with as-cast bore and centreless-ground on the outside diameter to limits of $+\frac{1}{32}$ to $+0{\cdot}015$ in. above nominal diameter, in sizes from $1\frac{1}{4}$ in. o.d. $\frac{3}{4}$ in. bore to $2\frac{3}{4}$ in. o.d. 2 in. bore, with a minimum wall thickness of $\frac{3}{8}$ in. and in lengths up to 6 ft.

Inverters for Aircraft Applications

Designed to provide, from a d.c. input supply which may vary from 25 to 29 V, a three-phase output of 200 V, 400 cps, 3 kVA at any power factor between 0·8 lag and 0·95 lead, the new inverters produced by the Aircraft Electrical Division of The Plessey Company Limited, of Ilford, Essex, are believed to be unique in Great Britain, because of their extremely high power/weight ratio. Each unit weighs only 60 lb, the overall dimensions, including the integrally mounted control panel, being $19\frac{1}{2} \times 7\frac{1}{16} \times 11\frac{7}{8}$ in. high.

These inverters, which are suitable for providing current for aircraft instruments, radar, and allied equipment, are self-cooled up to 10,000 ft and are capable of operating on full load in ambient temperatures between —30 and + 45°C. Under all these conditions, output voltage is held to a tolerance of $\pm 2\frac{1}{2}\%$ of 200 V and frequency to $\pm 3\%$ of 400 cps. These close tolerances are maintained by means of two control circuits, voltage control being by means of a carbon-pile regulator with a compounding transformer, and frequency control by means of a centrifugally operated carbon-pile governor of novel design. Both circuits are integrally mounted, and the control panel also contains the starting-gear and radio interference-suppression components.



The d.c. motor consists of a shunt-wound machine incorporating a compensating winding and a speed-control winding, the latter being fed from the control panel. In addition, a swamp resistance is connected in series with the shunt winding to compensate for the large variation in ambient temperature in which the inverter has to operate. The cooling fan of the machine is capable of drawing cooling air through 20 ft of straight ducting. The machine is fitted with a flame-trap at the air outlet, ensuring safe operation in an atmosphere which may become contaminated with explosive vapours.

AGRICULTURE

AUTOMOTIVE INDUSTRIES

EARTH MOVING • MACHINE TOOLS

MECHANICAL HANDLING

MARINE ENGINEERING • GAS INDUSTRY

WHATEVER THE JOB

THERE'S A

DUNLOP

FLEXIBLE PIPE

TO CARRY IT THROUGH

Dunlop Technicians will always advise on any problems concerning installation of Flexible Pipes. Write please to :—

DUNLOP RUBBER COMPANY LIMITED · ST. GEORGE'S ROAD · COVENTRY · TELEPHONE: COVENTRY 64171

6H/903

ADDITIONAL ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

A Method for the Direct Reduction of Iron-Ore Concentrate by Carbon Monoxide without Melting.
By O. STELLING and I. PERESWETOFF-MORATH. (From *Jernkontorets Annaler, Sweden*, Vol. 141, No. 5, 1957, pp. 237–260, 12 illustrations.)

IF iron oxides in a fluidized bed are reduced by carbon monoxide at high temperatures, the process is disturbed by the fact that the grains stick to each other when a certain content of metallic iron is attained. However, if the reduction is accomplished under suitable conditions in a fluidized bed at a lower temperature (about 600°C), cementite is formed, instead of metallic iron, and no tendency to sticking can be observed. Under the conditions used, the formation of cementite is so rapid that the carbon monoxide does not decompose into carbon and carbon dioxide.

Reaction velocities have been determined for different hematite ores, as well as for oxidized and non-oxidized magnetites, and, as described in this paper, a technical process has been worked out, based on the experimental results obtained, and has been studied on a pilot-plant scale. The results are very promising. The method is continuous, and experience from other fluidization processes indicates that the size of the plant can be varied between wide limits. The capital investments necessary are fairly small, the risks of scaffolding are entirely eliminated, and the heat economy can be estimated to be as good as that obtained with the Wiberg-Söderfors method. The cementite is resistant to air and is not pyrophoric. Cementite or a mixture of cementite and wüstite as the end-product opens up new possibilities for further processing. In addition, the method can be easily incorporated in a continuous system.

Compared with the method of reduction by hydrogen in a fluidized bed, as introduced in the U.S.A., the method described has a number of advantages. Thus, ordinary atmospheric pressure is used, and no cooling or heating cycles for the reduction gas are necessary. Furthermore, it would appear that it should not be impossible to use either oil or natural gas as raw materials for the reduction gas.

Optical Studies of Crazed Plastic Surfaces.
By S. B. NEWMAN and I. WOLOCK. (From *Journal of Research of the National Bureau of Standards, U.S.A.*, Vol. 58, No. 6, June 1957, pp. 339–350, 18 illustrations.)

WHEN transparent thermoplastics such as polymethyl methacrylate or polystyrene are exposed to a sufficiently high tensile stress or to solvents, deterioration of their optical properties occurs. This deterioration results from the formation of cracks which impair light transmission, cause optical aberrations, and reduce the strength properties of the material. Commonly known as "crazing", this phenomenon is encountered in a variety of products, and is obviously of considerable economic importance to manufacturers and users of plastic items. A number of investigators have reported the results of work on the mechanism, characteristics, and elimination or prevention of crazing. However, crazing remains a serious consideration in plastics applications and many aspects of the problem require intensive study.

As described in this paper, optical studies were made of crazed surfaces, principally those of cast polymethyl methacrylate. The techniques used for these studies were multiple-beam interferometry and light and electron microscopy. The dimensions of the craze cracks produced by short-time stress crazing and by stress-solvent crazing were determined by these techniques. Stress-crazed specimens contained the smallest cracks observed during this investigation. The dimensions determined in some of these specimens were :—Length, 2 to 10 μ ; width, 0·1 to 0·25 μ ; and depth, 0·05 to 0·15 μ. In other specimens and in solvent-crazed surfaces the dimensions were larger. The craze cracks did not appear to approach dimensions unresolvable by the electron microscope but, instead, appeared to have a minimum crack length.

An elevation of the surface in the vicinity of craze cracks was observed, of the order of 0·02 μ for cracks produced by stress-crazing and 0·3 μ for those produced by stress-solvent crazing. This rise was observed in crazed specimens while still under load. The typical surface displacement was noticed in specimens crazed in tension produced by flexure, as well as in pure tension, and was observed in polystyrene and in polymethyl alpha-chloroacrylate, as well as in polymethyl methacrylate.

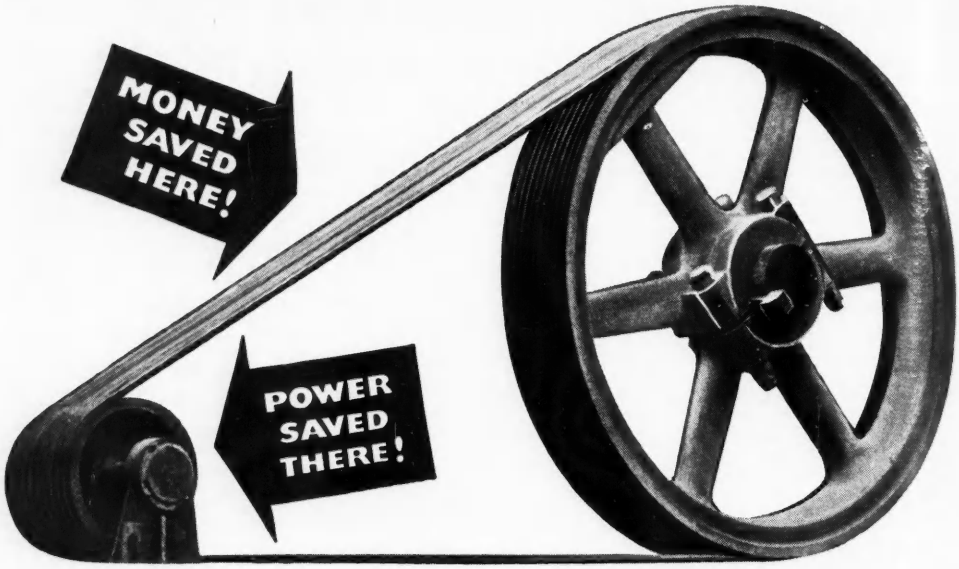
Some crazed specimens, in which the crazing had apparently "recovered" when viewed with the unaided eye, still exhibited the surface displacement typical of crazed specimens. Experiments conducted by heating stress-crazed specimens and stress-solvent-crazed specimens to accelerate the recovery of crazing indicated that surface recovery is essentially complete in the former case but not in the latter. This difference in recovery behaviour is probably due to the nature of the deformation associated with the two types of crazing.

Tensile specimens to which loads had been applied that were slightly too low to produce immediate crazing did not exhibit surface displacements typical of crazed specimens.

Investigation of the Velocity Field of a Non-Rotating Bladeless Impeller by the Electrolytic Tank Method.
By T. SZENTMÁRTONY and A. VERBA. (From *Acta Technica Academiae Scientiarum Hungaricae, Hungary*, Vol. 16, No. 3/4, 1957, pp. 371–382, 13 illustrations.)

THE object of the investigation described in this paper was to obtain data providing a basis for determining whether there was any possibility of separation occurring at the inlet fairing of a fan impeller with an undisturbed velocity field at the positions of the blades. For this purpose, it was necessary to obtain measured values for the absolute meridian-velocity field, particularly along the inlet fairings and at the blade positions. Measurements were made by the electrolytic tank method, based on the fact that the flow velocity at any point around a body of revolution is proportional to the voltage gradient at the corresponding point of the tank, in the direction of the velocity.

The wooden electrolytic tank was designed as an elbow-shaped pattern of varying depth, representing one segment of the impeller, the impeller space being filled with water and the electrodes fitted at the two ends of the elbow-shaped pattern. An electrode voltage of 14 V was used and, to prevent electrolysis, a 300-cps voltage was taken from a signal generator. A needle of 0·25 mm diameter, mounted on a horizontal holder, was dipped into the electrolyte at the various positions investigated. The needle divided the resistance of the water between the end-electrodes and the needle into two parts, which were connected with two other non-inductive resistances in a Wheatstone-bridge circuit. A voltmeter was con-

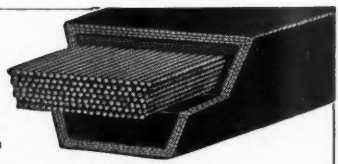


...When Goodyear V-Belts are on the job!

You get longer belt life, more efficient transmission with Goodyear V-Belts. There's a wide range of these 'job-designed' belts to suit every kind of drive — from huge multi-V installations to small F.H.P. applications. The Goodyear Service will help you select the right V-Belt for the job and advise on optimum working conditions. In this way, you can be sure of the greatest economy and the elimination of costly shutdowns.

Consult your Goodyear Industrial Rubber Distributor or write to:

The Goodyear Tyre & Rubber Co. (G.B.) Ltd., Industrial Rubber Products Dept., Wolverhampton.



E.C.V.

FOR MULTI-V INSTALLATIONS

Withstand high starting torques, sudden shocks and pulsating loads. Minimum stretch and creep. Tough, rubber-impregnated fabric preserves the belt section, resists side-wear and gives positive grip.

F.H.P.

FOR FRACTIONAL HORSE POWER LOADS

Will absorb the shocks and strains of frequent starting and stopping. Also designed to withstand the high rate of flexing arising from the compactness of short centre, high speed, small pulley drives.

GOODYEAR INDUSTRIAL RUBBER PRODUCTS

V-BELTS · TRANSMISSION BELTING · CONVEYOR BELTING · INDUSTRIAL HOSE

nected across these resistances, i.e., in parallel with the end-electrodes ; the centre point between the resistances was earthed and the earth lead and the screened output lead from the needle were connected to the input terminals of an amplifier acting on the Y-plates of an oscilloscope. The X-plates were connected to the secondary of a transformer with two primary windings, of which one was fed from the 300-cps signal generator, while the other, in parallel with the voltmeter, received the output from the end-electrodes. The oscilloscope was used as a null-indicating instrument.

The results obtained can be summarized as follows :—

(1) There is an appreciable difference between the meridian velocities at the front disc and the rear disc, even with impellers of reduced width.

(2) In further contrast to the usual average-velocity calculations, it was found that the velocity diminishes rapidly along the front disc, whereas it is nearly constant along the rear disc, so that the possibility of a twisting of the blades may require examination.

(3) The maximum velocity on the curved front disc depends mainly on the impeller width, being nearly doubled when the width is increased from 32 to 81 mm, whereas the effect of the hub on maximum velocity is much less pronounced.

(4) The ratio of the maximum meridian velocity to the velocity at the end of the curved transition of the front disc is approximately independent of the hub, but is increased by 50% when the impeller width is increased from 32 to 81 mm.

(5) The maximum meridian velocity is at about 53 deg. on the circular transition of the front disc (0 deg. being on the inlet side of the transition) for a narrow impeller, and is not altered by the hub ; for a wide impeller, the maximum is at about 30 deg. without a hub, and drops even further with various hubs.

Strain-Ageing of Aluminium-Magnesium Alloys.

By A. R. C. Westwood and T. Broom. (From *Acta Metallurgica*, *U.S.A.*, Vol. 5, No. 5, May 1957, pp. 249–256, 12 illustrations.)

Strain-ageing arising from the interaction between solute atoms and dislocations can greatly influence the behaviour of alloys under various conditions of mechanical testing. The yield-point and repeated yielding phenomena found during the tensile testing of mild steel are well known and are caused by strain-ageing involving interstitial carbon and nitrogen atoms. However, in substitutional alloys these effects are not so marked, because the interaction energy between solute atoms and dislocations is much less for substitutional atoms (estimated at about 0·2 eV for magnesium in aluminium) than for interstitial atoms (about 0·5 eV for carbon in iron). The concentration of solute atoms required to produce recognizable strain-ageing effects is thus larger for substitutional alloys than for interstitial alloys. For example, at room temperature, only about 10^{-7}% of carbon in iron can give rise to a sharp yield point, but in aluminium at least 10^{-1}% of solute element is required.

The authors consider that the low activation-energy values observed for aluminium-magnesium alloys may be explained by taking into account the movements of excess vacant lattice sites produced by the cold work prior to the ageing treatment. The investigation described in this paper was therefore carried out to examine this vacancy-assisted strain-ageing hypothesis and to obtain accurate values of the activation energies for strain-ageing in aluminium-magnesium alloys. High-purity alloys were used, containing between 0·5% and 3% magnesium by weight. In these experiments it was assumed that the yield drop (the difference between the upper and lower yield stresses) could be used as a measure of the strain-ageing that had occurred in a specimen during a given strain-ageing treatment. Thus, tests were performed in which tensile specimens were prestrained fixed mounts at liquid-air temperature and then aged for various times at various temperatures between 208 and 369°K. The yield drop occurring during the subsequent tensile test at liquid-air temperature was recorded. From a consideration of the variation in yield drop with time and temperature of ageing it was possible to determine the activation energies for strain-ageing in the several alloys used.

These investigations are described and some tentative ideas put forward in explanation of the results obtained. The strain-ageing of the aluminium-magnesium alloys was studied as a function of composition and prestrain (1 to 15% extension). Activation energies in the range 0·27 to 0·47 eV have been deduced. In alloys of high (3%) magnesium content the early stages of strain-ageing are considered to be associated with rapid diffusion near dislocation cores but, in the later stages and in dilute alloys, strain-ageing is caused by the migration of magnesium atoms, aided by the lattice vacancies produced during the prior strain. Thus, the activation energy is that required for movement of vacancies under the prevailing conditions. During prolonged ageing of 1 and 3% magnesium alloys at room temperature and after shorter ageing times at higher temperatures, some form of precipitation apparently occurs.

An Ignitron Contactor for Direct-Press Drives.

By D. L. Pettit and R. Montross. (From *Applications and Industry* (*A.I.E.E.*), *U.S.A.*, No. 31, July 1957, pp. 110–113, 5 illustrations.)

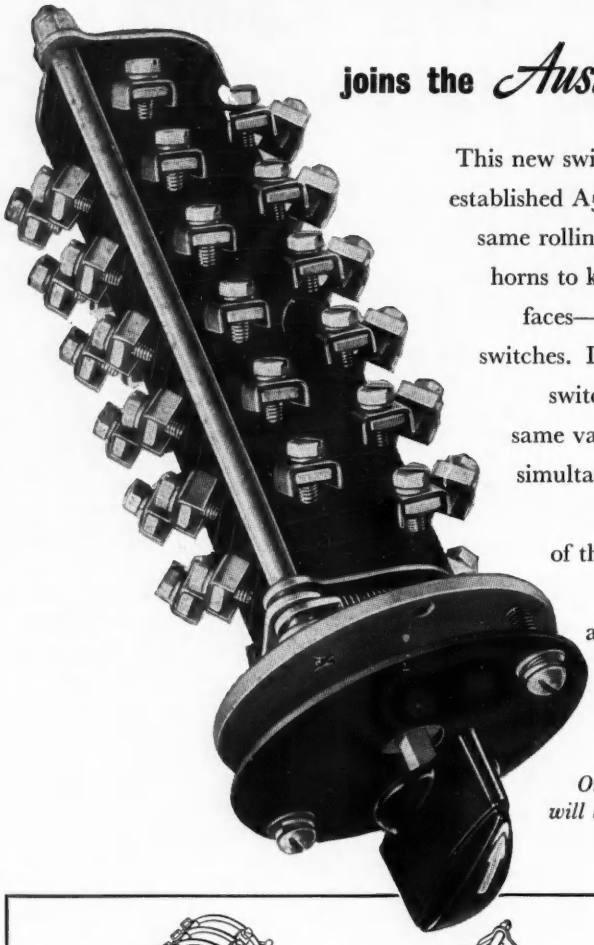
The usual method of allowing the main drive motor of a large draw-press to run continuously while the press is started and stopped by controlling a clutch has become extremely costly because of production interruptions for clutch maintenance. By gearing the drive motor directly to the crank of the press, and starting and stopping the motor for each operating cycle, the problem of clutch maintenance is eliminated. However, as motor horsepowers increase, it becomes evident that the problem of maintenance has not been eliminated, but merely transferred from the clutch to the motor and its controller.

Since the motor is started and stopped for each stroke of the press, a large contactor must close and open the circuit for each cycle of operation. The high rate of operation causes rapid erosion of the contact tips, and contributes to relatively short mechanical life of the contactor. Shock-loading of the gear train each time the motor is connected to the line causes damage to gears, shafts, and keyways, eventually requiring complete overhaul of the press. Additional contributions to contactor distress and motor maintenance are produced during die set-up procedures, when the operator may repeatedly inch the press through most of a complete press cycle. In these circumstances, arcing is present at the contactor tips. The motor may be subjected to very severe transients which produce additional thermal and mechanical stresses in rotor bars, rings, and phase windings. Inrush currents to the motor may be sufficient to produce welding of the main contactor, shutting down the press.

The ignitron contactor for direct press drives is a new approach to relieving these difficulties. By connecting a pair of ignitrons back to back in each of the three phases, a contactor is obtained which is capable of closing the circuit for each operating cycle and which can still render long, trouble-free service. The use of ignitrons as contactors permits utilization of their useful characteristic of reducing output voltage by retarding their firing angle, commonly known as phase-back. By incorporating phase-back action with slope control, the motor terminal voltage is permitted to build up to nominal value in a few cycles. Thus, a cushioned start of the motor is obtained with negligible increase in starting time.

The cushioning action of the phase-back circuit has several useful functions. It minimizes the effect of the d.c. transient in the motor, thereby reducing the com-

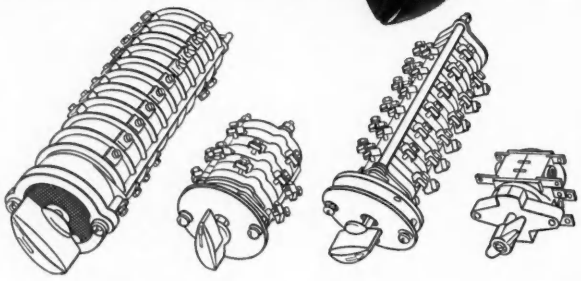
Now the A15—



joins the *Austinlite* rotary switches

This new switch is identical in principle to the well established A50 and A30 rotary switches. It has the same rolling, self-cleaning contacts with extended horns to keep any arcing away from the contact faces—a feature exclusive to Austinlite rotary switches. It has a similarly powerful and positive switch mechanism, and can be built in the same variety of forms to switch in sequence or simultaneously very large numbers of circuits. It is extremely compact, the smallest of the Austinlite multi-cell rotary switches. It bridges the gap between the A30 and the little single-cell 10-amp switch. Delivery, on standard applications, can now be made in four weeks.

Our brochure "SIMPLIFIED SWITCHING" will tell you more about the advantages of Austinlite Rotary Switches. May we send you a copy?



The four Austinlite Rotary Switches—A50, A30, A15 and A10

Austinlite

ROTARY SWITCHES

tailor-made by

STONE-CHANCE LTD.

(Makers of Sumo Pumps and Stone-Chance lighthouses). Crawley, Sussex

ponent of braking torque caused by this transient. Slack in the gear-train is taken up softly, instead of with a sharp hammer blow as would occur when the motor is started at full line voltage. Magnetic forces within the motor are reduced at the moment of voltage application, lessening stress to the rotor conductors and reducing working of the phase windings to the point where motor life is multiplied. Smaller increments of movement are possible when inching the press, because the small relays used to control the ignitron circuits are much faster in response than the large mechanical contactors normally used to control motor current directly, making the press respond more quickly for inching operations. An incidental benefit is the great reduction in the noise level of controller operation when ignitrons are used.

An Evaluation of Tests for Forgeability.
By A. B. DRAPER. (From *ASTM Bulletin, U.S.A.*, No. 223, July 1957, pp. 62–68, 10 illustrations.)

MANY attempts have been made to compare the forgeability of certain types of alloys. However, the wide variety of forged shapes, and the fundamental differences between the alternative procedures by which a particular part can be forged, make it very difficult to define or measure forgeability. The present survey of literature and of established commercial practices indicates a pronounced lack of agreement in this respect.

Forgeability resolves itself into measuring three characteristics, i.e., flow stress, or internal friction; ductility; and friction coefficient, or external friction. Of these, flow stress and ductility are basic properties of the metal. The friction coefficient is a complex physical constant depending on the mechanical and chemical properties of the surfaces of the work and the tool in contact, and on the lubricant applied to reduce friction and protect the die surfaces. In hot-forging, temperature and speed are two important variables. In fact, the range of temperatures and speeds which can be used for a given alloy might be considered a fourth component of the term forgeability.

From the discussion on forgeability tests presented in this paper, the following primary facts emerge :—

The forgeability tests now used have been primarily designed to test materials prior to forging the cast ingot into a billet, or prior to rolling billets, plate, and sheet. No standard forgeability test has been developed for closed die forging.

Many of the forgeability test methods proposed necessitate equipment other than forging presses and hammers.

Static tests, performed at slow speeds, frequently yield a different rating of the materials from those found in forging practice. They may either depreciate or enhance certain features of forgeability observed at higher rates of straining.

A practical forgeability test must supply values which clearly delineate or identify each of the three distinctly different characteristics previously mentioned. The two major variables which affect these three characteristics are the forging temperature and, particularly for certain types of materials, the forging speed. In addition, ductility depends greatly upon the type of forging and possibly also upon the same factors which determine friction. The frictional resistance depends particularly upon the lubricant. It may also be affected by the roughness of the die and blank contact surfaces.

The compression test, when fully evaluated by a set of force stroke curves, can supply all three components of forgeability. Several other tests have been used to evaluate the friction and flow stress in cold-forming operations, but these have not been evaluated for hot-forming. In addition, the use of a conical-mandrel indentation test and extrusion into a cavity have been proposed, but not evaluated. Some success in evaluating ductility by a bulging or expansion test has been achieved, but the work has not been completed.

An Appraisal of Ceramic Cutting Tools

(*Concluded from page 386*)

breaker, it is still probably advisable to use a carbide chip-breaker, and a useful rule of thumb is to position the chip-breaker at a distance equal to about twelve times the feed rate from the cutting edge of the tool, with a minimum distance of about $\frac{3}{32}$ in. Ground-in grooves can be quite successful with the right cutting conditions but have the disadvantage that they can be worse than useless if cutting conditions are changed appreciably. With either a clamped chip-breaker or a ground-in groove, it is better to have the cutting edge and the chip-deflecting edge not quite parallel, so as to prevent the curled chip from striking back onto the tip near the cutting edge.

Ceramic and sintered oxide tools have been used for boring operations and non-single-point cutting. Milling tests have been partially successful, inasmuch as soft non-ferrous metals were cut, but results with steels have been very poor indeed. One American manufacturer has marketed reamers with oxide inserts, but no objective report on these is available.

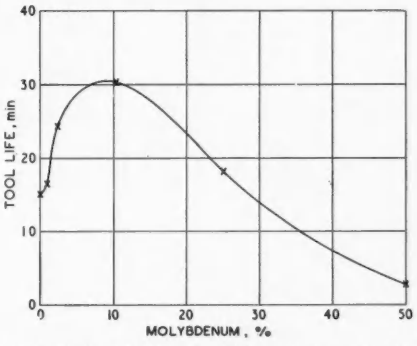


Fig. 8. The effects of additions of molybdenum to a ceramic tool, when cutting a 45-ton steel, using a cutting speed of 380 fpm, a depth of cut of 0·160 in., and a feed of 0·022 in./rev.

In concluding this review, it is perhaps apposite to mention the attempts which have been made to produce ceramic/metal alloys. So far, the work has been on a very limited scale and has been virtually restricted to chromium and molybdenum. Fig. 8 shows the effect of adding up to 50% of molybdenum to a ceramic.[7] The tool life is increased but the amount of metal to be added appears to be fairly critical. Reports[7] indicate a good degree of success on steels when using ceramic/metal tips of this type.

REFERENCES

(1) E. J. TANGERMAN : "What we should know about ceramic tools" ; *American Machinist*, Special Report No. 417, March 12, 1956.
(2) H. D. MOORE and D. R. KIBBEY : "Ceramic tool geometry and preparation" ; Paper No. 19, ASTE Conference, Houston, 1957.
(3) V. I. ZHIKHAREV : "The use of cutting tools with ceramic tips" ; *Stanki i Instrument*, No. 2, 1956, pp. 19–21.
(4) T. POGÁNY : "Results obtained with the application of ceramic tips in machining" ; *Gép*, Vol. 7, 1955, pp. 471–476.
(5) A. B. ALBRECHT : "Single-point turning with ceramic tools" ; *Machinery*, Vol. 91, July 26, 1957, pp. 193–198.
(6) A. O. SCHMIDT, B. F. VON TURKOVICH, J. R. ROUBIK, and I. HAM : "Ceramic and carbide tool performance tests (Part II)" ; ASME Paper No. 57-SA-101, Semi-Annual Meeting, San Francisco, June 1957.
(7) W. RICHTER and G. KAMMERICH : "Einige Untersuchungen an keramischen und mischkeramischen Werkstoffen für Schneidplättchen" ; *Silikatechnik*, Vol. 6, No. 12, pp. 528–534.

NOW THERE ARE EIGHT

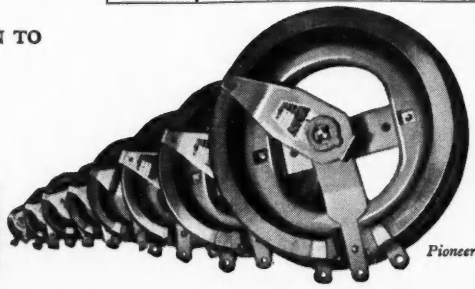
BERCO

TOROIDAL RHEOSTATS

So popular has the original range of five Berco rheostats become that three new models have been introduced. Like all Bercostats they have five important features:—

- VITREOUS ENAMEL BONDED
- HIGHEST MECHANICAL STRENGTH
- MAXIMUM ELECTRICAL PERFORMANCE
- MINIMUM SIZE IN RELATION TO POWER DISSIPATION
- CAN BE USED IN TROPICAL SITUATIONS WITHOUT MODIFICATION

Ohms ± 10%	CURRENT RATINGS							
	L.25	L.50	L.75	L.100	L.150	L.225	L.300	L.500
1	—	7.07	8.66	10.00	12.50	15.0	17.3	22.3
2	3.54	5.00	6.12	7.07	8.66	10.6	12.2	15.8
3	2.89	4.08	5.00	5.75	7.07	8.66	10.0	12.9
5	2.24	3.16	3.88	4.77	5.48	6.71	7.75	10.0
7.5	1.82	2.56	3.16	3.65	4.47	5.48	6.32	8.17
10	1.58	2.24	2.74	3.16	3.88	4.74	5.48	7.07
15	1.29	1.83	2.24	2.58	3.16	3.87	4.47	5.78
25	1.00	1.41	1.73	2.00	2.45	3.00	3.46	4.47
50	.707	1.00	1.23	1.41	1.73	2.12	2.45	3.16
75	.578	.818	1.00	1.15	1.41	1.73	2.00	2.58
100	.500	.707	.866	1.00	1.23	1.50	1.73	2.23
150	.408	.575	.707	.818	1.00	1.22	1.41	1.82
200	.354	.500	.612	.707	.866	1.06	1.22	1.58
350	.268	.378	.463	.535	.655	.803	.926	1.19
500	.224	.316	.388	.447	.548	.671	.775	1.00
1,000	.158	.224	.274	.316	.388	.474	.548	0.708
1,500	.129	.183	.224	.258	.316	.387	.447	.578
2,500	.100	.141	.173	.200	.245	.300	.346	.448
5,000	—	.100	.123	.141	.173	.213	.245	.315
7,500	—	.081	.100	.115	.141	.173	.200	.258
10,000	—	—	—	.110	.125	—	.173	.224
15,000	—	—	—	—	—	—	—	.163



Ask for list 613A, which gives full technical details and prices from :—

THE BRITISH ELECTRIC RESISTANCE CO. LTD.

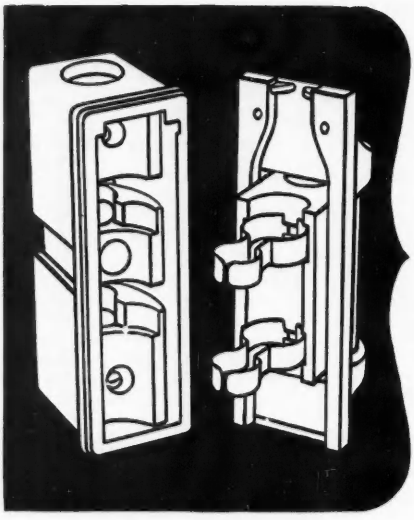
Queensway, Ponders End, Middlesex.

'Phone : Howard 2411
'Grams : Vitrohm Enfield

Pioneers of the toriodally wound rheostats in England.

BERCO

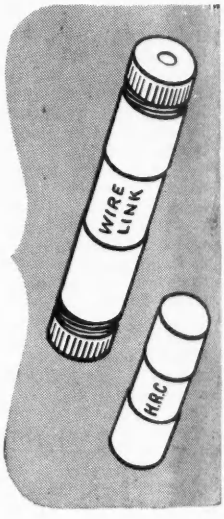
LR 1331-BXH



The Two-In-One Unit

REWIRABLE OR H.R.C.

One of the outstanding features which have made the new "H" Type Slydlok Fuse universally popular is its ability to accept either Rewirable Fuselinks or H.R.C. Cartridge Fuses without any modification to the base or holder, a simple and economical arrangement which saves time, trouble and tempers.



Further advantages of the "H" Type and details of other fuses in the Wilcox range are given in our latest Catalogue, a copy of which will be sent to you on request.

EDWARD WILCOX & CO. LTD., WYTHENSHAWE, MANCHESTER, 22.
Tel: WYT 2235/6/7. Grams: "Slydlox" Manchester.
London Office: Fulwood House, Fulwood Place, W.C.I. Tel: CHAncery 2206.

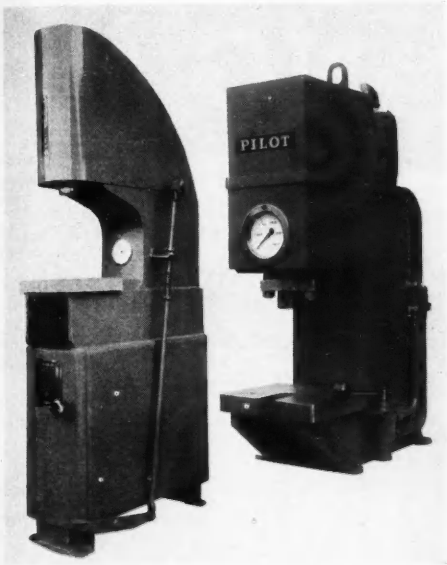
SLYDLOK
H Type Fuse

dmEW83

New Materials, Processes, and Equipment

HYDRAULIC AND BENCH PRESSES

Two new presses, the No. 7 12-ton hydraulic press and the No. 8 3-ton bench press, have been announced by Pilot Works Ltd., of Bolton. These items, which were featured at the recent Engineering, Marine, and Welding Exhibition, are shown in the illustration, in which the No. 7 press is on the left and the No. 8 on the right.



Model No. 7 has a work-table with a surface of 12 × 12 in. and has a daylight, stroke, and throat dimensions of 12, 6, and 12 in. respectively. This press has a foot-pedal control with an alternative pressure valve, adjustable from 0 to 12 tons. The free-travel down-speed of the stroke is 3 sec, with a return speed of 4 sec, while the travel speed under load is $\frac{1}{4}$ in. per sec. This model, which is powered by a 2-hp electric motor, occupies a space of 3 × 1 × 6 ft high.

Model No. 8 is powered by a $\frac{1}{3}$-hp electric motor, providing free-travel speeds of 1 sec down and $1\frac{1}{2}$ sec return, and a travel speed under load of $\frac{3}{8}$ in. per sec. The size of the work-table is 10 × $8\frac{1}{2}$ in., the stroke is $3\frac{3}{4}$ in., and the press, which is controlled by a hand lever, has a daylight and throat dimension of $7\frac{1}{4}$ and $5\frac{3}{4}$ in. respectively. The overall dimensions of the press are 1 ft 9 in. × 1 ft 1 in. × 3 ft 1 in. high.

ENGINE-SPEED CONTROL UNIT

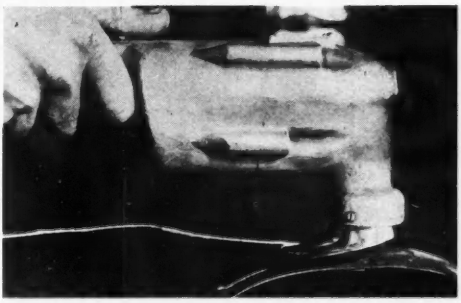
The Bryce " Speedlock ", introduced by Bryce Berger Limited, of Staines, at the recent Engineering, Marine, and Welding Exhibition, is a powerful all-purpose servo-governor which provides extremely accurate engine-speed control. Operating on an entirely new principle, the " Speedlock ", the present model of which is suitable for most engines in the 500 to 5000 hp range, is hydraulically connected to a remotely driven gear-pump and can be fitted in any convenient location.

The important characteristic of the " Speedlock " is its new concept of speed sensing, in which an engine-driven gear-pump displaces a hydraulic fluid through a nozzle to impinge against a spring-biased scoop. The faster the engine runs the greater the force the jet exerts. This simple mechanism has an extremely low moment of inertia and therefore responds very rapidly to speed changes. Moreover, there are no sliding pistons to introduce friction or become contaminated with dirt.

The advantages afforded by this new principle are particularly great when it is used to feed a servo-amplifier. The amplifier requires a source of hydraulic fluid to provide its motive power, and the same source serves to operate the scoop by placing the nozzle and scoop chamber in tandem with the amplifier circuit. As there are no other rotating parts, a single pump, divorced from the " Speedlock ", operates the whole mechanism and offers the advantage of utilizing any convenient drive, irrespective of its location and attitude.

PNEUMATIC SHEAR

Shown for the first time at the recent Engineering, Marine, and Welding Exhibition, the new LBK 31 pneumatic shear manufactured by Atlas Copco (Great Britain) Ltd. has a cutting speed of 20 fpm in 14-swg mild-steel sheet and, by virtue of its low weight of $5\frac{3}{4}$ lb and compact design, is easy to operate. The handle is made as an extension to the upper part of the motor body, which affords protection for the operator's hand. The LBK 31 is powered by an Atlas Copco vane-type air motor, with a low air consumption.



A new design of tubular inlet valve ensures that pressure losses are kept at a minimum, and for this reason the power is unusually high in proportion to the size of the motor. Lubrication is achieved with a built-in lubricator which automatically supplies the motor with oil, and the silencer, which is incorporated in the body of the machine, ensures quiet operation. To suit sheets of varying thickness, the renewable cutting blades can be quickly adjusted.

INDUSTRIAL PROCESS TIMER AND TEMPERATURE-CONTROL UNITS

Two new instruments for industrial purposes, a process timer and a temperature-control unit, are announced by Airmec Limited, of High Wycombe, Bucks. Both types of unit are housed in a small robust case, as shown in the illustration, which depicts the process timer.

The timer, type N237, provides an accurately timed switching facility for industrial control purposes over the range of 1 to 10 sec and 10 to 100 sec. The starting signal may consist of the connection or disconnection of a pair of contacts and may be either a short pulse or a contact longer than the timing period. The versatility of the timer also allows it to be connected in a number of different ways, e.g., two timers back to back, two or more in tandem, or three or more in a ring circuit. The

SLIDEWAY GRINDING

HEADS FOR HORIZONTAL AND VERTICAL GRINDING WITH THE BROCKHOUSE UNIT GRINDING HEAD AND TRUING DEVICE

- ★ Easily adaptable on most standard machines.
- ★ Rapid and accurate.
- ★ Slideway Grinding Enquiries invited.

BUILDERS OF SPECIAL MACHINE TOOLS

AT SETTING

Write for descriptive folder to :—

J. BROCKHOUSE & CO. LIMITED

Machine Tool Division

ELMS WORKS · PENN ROAD · WOLVERHAMPTON

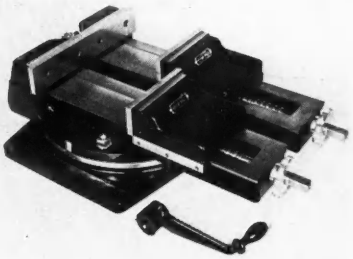
Phone: Wolverhampton 23801

unit can be supplied with the time control adjustable by means of a knob on the front panel or by a sealed screwdriver slot to prevent tampering.

The temperature control unit, type N241, is a highly sensitive robust instrument suitable for incorporation in industrial installations. It operates over the temperature range —70°C to +600°C, control being effected by a heavy-duty output relay fitted with three sets of contacts, i.e., 8-A single-pole changeover, 1-A single-pole changeover, and 1-A single-pole make-before-break. The sensitive element is a small platinum resistance, extremely robust and completely stable. It is available in two forms, either $\frac{1}{8}$ in. diameter by 2 in. long, or $\frac{1}{4}$ in. diameter by 6 or 24 in. long. Operation of the output relay is effected by a 0·1% change in the value of the temperature-sensitive resistor, representing a temperature change of about 0·4°C.

HEAVY-DUTY TWIN-JAW VICE WITH TWO-SPEED MECHANISM

Fitted with two independent 6-in. wide sliding jaws, the " Hylo " Twin-Six vice announced by Alfred Herbert Ltd., of Coventry, is fitted with a graduated swivel base and incorporates an automatic differential two-speed mechanism which provides a convenient solution to the problem of gripping large workpieces.



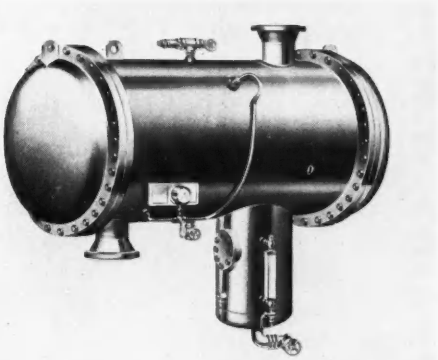
The operation of a vice of this design with conventional lead-screws would be very tedious and would detract considerably from the advantage of holding with a double grip. In the " Hylo " vice, however, this disadvantage is overcome by the extremely rapid opening and closing of both moving jaws with the two-speed screw. Each shaft moves its jaw at a rate of 0·5 in. per revolution of the handle. Contact with the workpiece automatically changes the pitch to 0·1 in. advance per revolution, a final quarter-turn being all that is necessary to grip the work firmly. A further advantage is the ability to double-load smaller pieces, even if they are not of exactly the same thickness. The two-speed device is fully automatic and operates at any point between fully open and closed. The mechanism is completely enclosed, and readily removable filler plates in progressive lengths are provided for protection of each lead-screw from swarf or chippings.

Should the vices be located on the bed of a machine in such a way that the handles cannot be fully revolved, the finger-grip hand-wheel fitted to each shaft provides rapid positioning of the moving jaw prior to gripping. Thereafter, full grip and release are obtained without removing the handle from the shaft.

BULK-FUEL FILTER-SEPARATOR

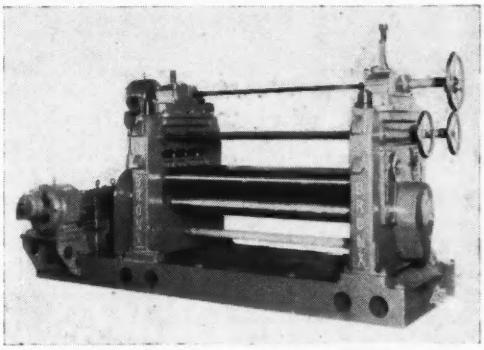
The new " Purolator " bulk-fuel filter-separator produced by the Automotive Products Company, Ltd., of Leamington Spa, is not only of compact design but performs two important functions simultaneously, i.e., it extracts both water and solid particles from fuels. Although primarily intended for aircraft fuelling operations, these filters, which are available in a range suitable for flow rates from 250 to 750 gpm, are equally suitable for use in diesel fuel-storage depots, large engine testhouses, dockside installations, etc.

The efficiency of water removal naturally depends to some extent on operating conditions, but these filter-separators are stated to have proved 99·98% efficient in most circumstances. Insofar as solid impurities are concerned, all solids greater in size than 5 microns are removed by the filter, together with a large proportion of smaller particles.



7-ROLL PLATE-LEVELLING MACHINE

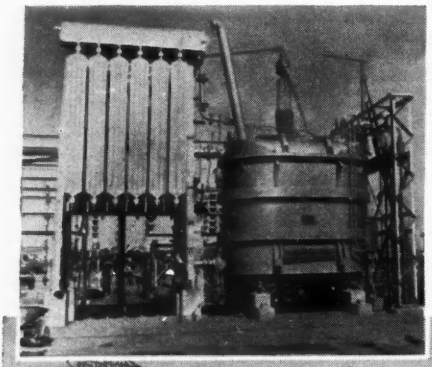
A new 7-roll plate-levelling machine, produced by The Bronx Engineering Co. Ltd., of Lye, near Stourbridge, and shown for the first time at the recent Engineering, Marine, and Welding Exhibition, comprises seven carbon-steel straightening rolls, of which the three bottom rolls are 10½ in. in diameter, the two outer top rolls 9 in. in diameter, and the two centre top rolls 10½ in. in diameter. The bottom rolls are driven, all top rolls being idle and provided with a means of adjustment to suit the material. All rolls can be adjusted simultaneously, whilst the two outer top rolls have separate handwheels for setting. Indicators are provided to show the roll settings.



The machine, with a 25-hp, 960-rpm main drive motor and a 5-hp, 960-rpm motor for adjusting the top rolls, is capable of handling plates up to ½ in. in thickness and 6 ft in width, and operates at a speed of about 20 fpm.

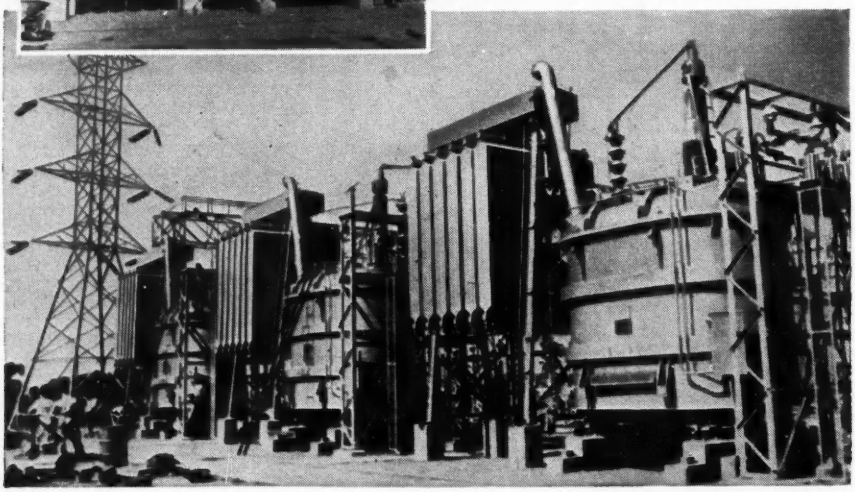
More Power for Australia...

220 kV TRANSFORMERS



Industrial expansion in Australia has, inevitably, increased the demand for electric power. As part of their development programme, the State Electricity Commission of Victoria are installing a total of seventeen BTH 220 kV, 15 MVA, single-phase transformers at substations in the Melbourne area.

The illustration shows part of the installation at Brunswick substation with, inset, one of the BTH units.



BTH manufacture all types of transformers — also cast-in-concrete and oil-immersed reactors, step-voltage regulators, arc-suppression coils, oil-testing sets, oil filter presses.

BRITISH THOMSON-HOUSTON

THE BRITISH THOMSON-HOUSTON COMPANY LIMITED · RUGBY · ENGLAND

Member of the AEI group of companies

A4888

NEWS OF THE MONTH

PERSONAL

The Council of the Institution of Production Engineers announce that **The Right Hon. The Earl of Halsbury, F.R.I.C., F.Inst.P., M.I.Prod.E.,** has been elected President of the Institution for the year 1957–58. Lord Halsbury has been since 1949 Managing Director of the National Research Development Corporation, which was set up under the Development of Inventions Act, 1948, mainly to ensure the development and exploitation of inventions resulting from public research.

Mr. H. G. Gregory, M.I.Prod.E., the present Chairman of Council, has been re-elected for a further year of office.

Mr. H. W. Bowen, O.B.E., M.I.Mech.E., M.I.Prod.E., has been re-elected for a further year of office as Vice-Chairman of Council.

Sir Nevil Macready, Bt., has been appointed Manager of Supply Department of Mobil Oil Company, London, S.W.1. He will report to **Mr. J. A. Paul,** who, since the beginning of this year, has carried out the dual function of Director and Manager of this Department.

Babcock & Wilcox Ltd. announce the appointment to their Board of Directors, on 11th June, 1957, of **Mr. Iain Maxwell Stewart, B.Sc., A.M.I.Mech.E., M.I.N.A., M.I.Mar.E.,** and the **Rt. Hon. Lord Bridges, P.C., G.C.B., G.C.V.O., M.C., F.R.S.**

Associated British Oil Engines Marine (Mirrlees) Limited, Stockport, have made a number of new appointments.

Mr. G. W. Thwaites, A.I.Mar.E. has become Sales Manager. He has, since 1946, been the company's representative in the North Coast Area. **Mr. M. W. Dunham,** who for the past two years has represented the company on the East Coast, has been appointed London Manager. **Mr. G. E. Cook,** previously on the design staff of William Doxford & Sons, succeeds Mr. Thwaites. **Mr. R. S. Bickerton, B.A., A.M.I.Mech.E.,** has been appointed Area Sales Engineer for the Liverpool and North West Coast. **Mr. A. A. Adley** becomes Area Sales Engineer for Hull and District. The company now has staffed service depots at Fleetwood, Aberdeen, and Grimsby, giving a full "round the clock" service.

Newly appointed Works Manager to Westool Limited, St. Helen's, Auckland, is **Mr. James F. Westaway, A.M.I.Prod.E.** He was previously with Wild-Barfield Electric Furnaces Ltd., as Assistant Works Manager.

The Northern Aluminium Company Limited announce that **Mr. C. J. Buchanan-Dunlop,** formerly of Birmingham Sales Office, has taken up the appointment of Manager of the Sales Administration Division, Banbury, and that **Mr. J. A. Ambler,** formerly head of the Metallurgical section of the Sales Development Division, takes charge of a newly-formed Market Research section of the Sales Department, also with office in Banbury.

It has been announced that **Mr. John S. Webster** is appointed Joint Managing Director of the Sheffield Twist Drill & Steel Company Limited, Sheffield, 11. Mr. Webster has been with the Company for 43 years and has been a Director for seven years. **Mr. C. P. Morley** is appointed Works Manager of the Summerfield Street Works, and **Mr. G. Orwin** Works Manager of the Solferino Street Works.

J. W. Simpson, A.M.I.E.E., has been appointed Chief Electrical Engineer to The Coniston Company, Engineering Consultants, Eagle House, Wimbledon. Before joining this Company he was an Electrical Engineer in the Technical Division of Unilever Limited, London.

On 1st July, **Mr. E. W. Jones, B.Sc., A.Inst.P.,** was appointed Sales Manager of Isotope Developments Limited, Aldermaston.

Mr. G. S. Webster, A.M.I.M.E.E., has been placed in charge of the Stoke-upon-Trent Sub-Office of The English Electric Company, where he will be responsible for the sale of all products. He previously specialized in the sale of "C" type transformer cores manufactured at the English Electric Liverpool Works. Mr. Webster succeeds Mr. R. Edwards who has left the Company.

British Oxygen Chemicals Limited have appointed two new Directors. They are **Mr. Leslie G. D. Sheldrake, B.Sc., A.M.I.Chem.E., A.R.I.C.,** who is appointed Works Director, and **Mr. J. M. Williams, B.A.,** who becomes Sales Director. The appointments were effective from 1st July.

Mr. M. Seaman has, from 1st July, moved from the Board of British Oxygen Gases Limited, where he will be Director responsible for equipment manufacture.

Springs

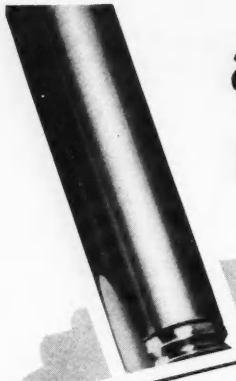
should be busy too!

Strength, resilience and the ability to stand up to resistance by night or day, these are the qualities of a good spring—a Lewis Spring. Send 2/6d. for our 40 page manual of technical data and learn a lot more about Lewis Springs.

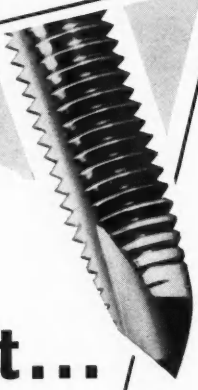
THE
LEWIS SPRING CO. LTD.
RESILIENT WORKS
REDDITCH
Tel: REDDITCH 720 - PBX
London Office: 122 High Holborn
W.C.1. Tel: Holborn 7470 and 7479.

LEAVE IT TO
Lewis
OF REDDITCH
SPRINGS. SPRING CLIPS
PRESSWORK. WIRE FORMS
VOLUTE SPRINGS

are YOU getting results like this?



155,078 holes before breakage



ESTABLISHED 1895

RITHERDON & CO. LTD.

SHEET METAL WORKERS AND ENGINEERS · ENAMELLERS AND ELECTRO-PLATERS

LORNE STREET · DARWEN
LANCS.

Our ref. GRR/JS.

TELEPHONE DARWEN 1028

English Steel Tool Corporation Ltd.,
North Street Works,
Openshaw,
Manchester.

9th July, 1956.

Dear Sirs,

We enclose a tap which has just broken after tapping 155,078 holes. Whilst we are rather disappointed not to reach the ¼ million mark we thought you might be interested in what, to us, would appear to be a fair performance!

Yours faithfully,
pp. RITHERDON & CO. LTD.

G. R. Richardson.

if not...

try

EaSiCut NOW!

Th's performance, typical of many results from "Easicut" Taps, was kindly reported to us by Ritherdon & Co. Ltd., Lorne Street, Darwen. A No. 1 B.A. tap was used on Bright Mild Steel Angle in a normal drilling machine fitted with a tapping chuck.

Makers of high quality Engineers' Cutting Tools for over a Century.

ESC

ENGLISH STEEL TOOL CORPORATION Limited

North Street Works, Openshaw, Manchester

A wholly owned subsidiary of English Steel Corporation Ltd., Sheffield.

BUSINESS NEWS

Birfield Limited, London W.1, announce the formation of a new subsidiary company, **Birfield Engineering Ltd.** whose special function is to be the co-ordination of engineering activities among the companies that make up the Birfield Group. The new Company's activities will include both the improvement of current, and the development of new, products for the Group. The Managing Director of Birfield Engineering Ltd. will be Mr. G. W. M. Lush. Mr. D. Bastow, B.Sc.(Eng.), M.I.Mech.E., and Mr. E. J. Rabson, A.M.I.Mech.E., M.S.A.E., will also be Directors of the new Company, whose headquarters will be in Birmingham adjacent to the factory of Hardy Spicer Limited in Chester Road as soon as the building is completed.

James C. Kay & Co. Ltd., Bury, Lancs, has recently become a wholly-owned subsidiary of **The Newall Engineering Co. Ltd.**, Peterborough.

The **British Steel Castings Research Association** announces that it has entered into an arrangement with the **Steel Founders' Society of America** for the exchange of information at their respective Annual Conferences. Each association will, in alternate years, invite the other to nominate a speaker to address its annual conference on a selected subject. The scheme is being initiated this year with an invitation from the S.F.S.A. for representatives of the B.S.C.R.A. to address the S.F.S.A. Technical and Operating Conference in Cleveland, Ohio, 11th-13th November, on the subject of the application of the graphite-rod resistor furnace to steel foundry practice, and the use in steel foundries of the immersion pyrometer for the measurement of liquid-steel temperatures.

An attractive new three-storey warehouse and office block has been opened by **The Glacier Metal Company Ltd.** opposite their main London factory at Alperton. The new building houses the main stores and administrative offices of the Replacement Bearing Unit—a self-contained part of the Glacier organization concerned solely with the storage, packaging, and merchandising of their automobile, truck, and tractor replacement bearings and bushes, for both Home and Export markets throughout the world. Apart from this new central warehouse, replacement bearings are stocked at the Company's depots in Manchester and Glasgow, and by over one hundred distributors throughout Great Britain. There are also extensive stocks in nearly all countries overseas, these being administered by the Company's Factory Representatives and Distributors.

It has been announced that the **Hawker Siddeley Group Ltd.**, and **John Brown & Co. Ltd.**, are to form a new company, to be known as **Hawker Siddeley John Brown Nuclear Construction Ltd.** (with a capital of £500,000), in which Hawker Siddeley and John Brown will be equal partners.

Sir James Bowman, Chairman of the National Coal Board, recently visited the Board's **Mining Research Establishment** at Isleworth to open new laboratories, the completion of which marks the final stage in a programme of converting what was formerly a film studio into a research establishment.

Bill Switchgear Ltd., Birmingham, 20, have now acquired larger premises for their Glasgow Branch office and stores. The new premises are located at 20 Sandyford Place, Sauchiehall Street, Glasgow, C.3. The new telephone number is Central 0960. Mr. J. D. Harris is the Manager of this Branch. The Company also intends, with effect from 1st August, 1957, to operate their London Branch office and stores from Gillingham House, 38-40 Gillingham Street, Victoria, London, S.W.1. The new telephone number will be TATe Gallery 0871.

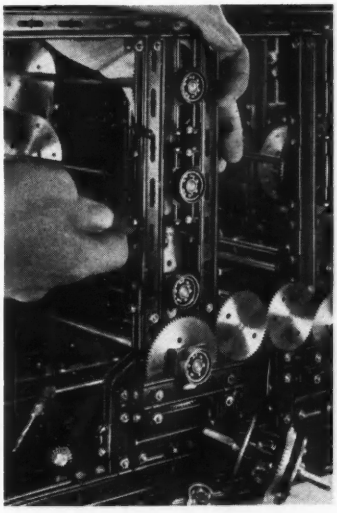
The Sheffield Twist Drill & Steel Co. Ltd., Sheffield, 10, announce the completion of new extensions and installation of new machinery at their subsidiary company, **Accurate Screw Threads Ltd.**, Precision Works, Hednesford, Staffs. The Company is now in a position to undertake further sub-contract work—complete assemblies, precision and repetition machining, etc., and Mr. G. Sharpe, the resident director will be pleased to deal personally with any enquiries: The Company is fully approved by the A.I.D. and A.R.B.

The new London Office address of **Wm. Beardmore & Co. Ltd.**, is 11 Hamilton Place, Piccadilly (Hyde Park Corner), London, W.1. Telephone, Grosvenor 8786.

Simms Motor Units Ltd., London, N.2, have appointed Mr. M. Ratschunas as their direct factory representative for Sweden. Mr. Ratschunas is already well known among tractor and commercial-vehicle operators in Sweden, having, since 1936, been looking after the interests of such well-known concerns as Nuffield Exports Ltd., Rootes Ltd., and Dunlop Rubber Co. Mr. Ratschunas' address in Sweden is Bergsgatan 35A.IV, Malmo.

Users of Jessop tool steels in the Birmingham area can now take advantage of a recent arrangement made between **William Jessop & Sons Ltd.**, Sheffield, and **George H. Alexander Machinery Ltd.**, West Bromwich.

Stocks of Jessop tool steels are now being held in the West Bromwich works, in particular G.1 special air-hardening nickel-chrome steel, K.4 special oil-hardening non-distorting steel and alloy C high-carbon high-chromium die steel. These facilities are backed by the substantial stocks maintained by William Jessop & Sons Ltd. in Sheffield.



FAC Industrial construction kits

for working models for experimental and demonstration purposes and for special apparatus.

Developed by MARK SYLWAN AB, Stockholm.
Full details from WEYCO (SALES) LTD.
18-20 Dames Road, London, E.7. (MARyland 4334)

dynamic technique

Your organization, however efficient, needs the driving-power of up-to-the-minute technical knowledge. Let SMITH'S supply you with the books that you must have to keep you fully in touch with the newest engineering techniques and the latest advances in research and operational economy.

● *Volumes not in stock can be obtained for you, and we shall be pleased to supply a list of standard works on any subject.*

W. H. SMITH & SON

HEAD OFFICE: STRAND HOUSE, LONDON, W.C.2.

BRANCHES THROUGHOUT ENGLAND AND WALES

CONSOLIDATED PNEUMATIC MAKE OVER 400 DIFFERENT MODELS OF POWER TOOLS

IT IS THE QUIETEST AIR-POWERED SCREWDRIVER IN THE WORLD!

This is the C.P. SUPERSONIC SCREWDRIVER

The C.P.—3008 screwdriver is a really effective step forward in overcoming production and assembly shop noise. It has a supersonic exhaust—the exhaust sound waves have been raised to a frequency higher than that audible to the human ear. Other efficiency features are—clutch, adjustable without the use of tools ; built-in speed control ; directional exhaust; all steel construction ; weight less than 2 lb. ; length only 9 inches ; full line of accessories. Write SP426 on a postcard for full details.

Consolidated Pneumatic

AIR COMPRESSORS
PNEUMATIC TOOLS
ELECTRIC TOOLS
CONTRACTORS EQUIPMENT
ROCK DRILLS · PUMPS
DIAMOND DRILLS

CONSOLIDATED PNEUMATIC TOOL CO. LTD.,
232 Dawes Road, London, S.W.6

CP104

The A.P.V. Company Ltd., Crawley, Sussex, has concluded an agreement with the **Rosenblad Company**, Stockholm, Sweden, for the exclusive manufacture and sale of the well-known Rosenblad heat exchanger in Great Britain. APV will also be responsible for its sale in the Commonwealth, except Canada, and in the Middle East. The manufacturing and selling rights were previously held by Messrs. Ashmore, Benson, Pease & Co. Ltd.

B.M.B. (Sales) Ltd., Crawley, Sussex, announce that they are now the Sole Selling Agents for Messrs. S. B. W. (Coldheading) Ltd., specialists in the manufacture of rivets and pins for the radio and electronics industry, aircraft construction and instruments.

CONTRACTS

Birwelco Limited, of Aston, Birmingham, British manufacturing licensees for Petro-Chem Iso-Flow fluid heating furnaces, have been awarded a contract for the supply of equipment to be used in Esso's butadiene plant at Fawley, Hants. The largest unit will consist of a specially designed Petro-Chem Iso-Flow furnace with a heat release of 192 million BTU/hr. Standing 180 feet high, the heater will be the largest Petro-Chem Iso-Flow furnace in use in the British Isles. Included in the contract are three smaller heaters and a quantity of heat-exchange equipment to be supplied by Birwelco's associate company, **Brown Fintube Great Britain Limited.** The value of the contract is approximately £250,000. **Foster Wheeler Ltd.** are responsible for the engineering and construction of the butadiene plant.

The contract recently awarded by the Scottish Region, **British Railways**, to **The Siemens and General Electric Railway Signal Co. Ltd.** for signalling at Perth covers colour-light signalling and electro-pneumatic operation of points at Perth General Station and extending over some nine miles of the main line. A route-relay interlocking installation operating over 400 routes will enable the work of thirteen existing signal cabins to be centralized in a new cabin south of the station, which will control the main line from Stanley Junction to Hilton Junction, respectively north and south of Perth, and the line to Dundee as far as Barnhill, a little over a mile from the General station. Routes will be set up by operating key switches corresponding to the beginning and end of each, and mounted in the appropriate positions on the track diagram. The main items of signalling equipment to be supplied include multi-aspect colour-light signals, electro-pneumatic point machines equipped with ground track locks and complete with air control units, position-light shunt and subsidiary signals, and a.c. vane-type track relays. The contract also covers compressor plant, diesel-driven standby power equipment, cables and cable routes, and air main equipment.

Servomex Controls Ltd. announce a valuable export order for the supply of 50 automatic voltage regulators to the South African Post & Telegraphs Department. As a result of a " private export drive ", overseas sales for the first 11 months of the current financial year are six times as high as last year, the previous record. This follows a visit to Europe last May by the Managing Director, Mr. Richard Steel, and a recent tour of Italy and Africa by another Director, Captain Andrew Yates, R.N.

Heenan & Froude Ltd., of Worcester, have received an order from **F. Perkins Limited**, Peterborough, for 20 of their DPY4 dynamometers. These machines will be used for production testing the range of Perkin's small diesel engines. **Rover (Gas Turbines) Limited** have ordered 18 DPX2 dynamometers, which will be incorporated in demonstration units for use in universities and technical colleges.

The British Thomson-Houston Company Ltd. have obtained an order valued at more than £1½ m. for two 120,000-kW C.M.E.R. turbo-alternator sets for the new Padiham " B " Power Station of the **Central Electricity Authority** (North West Merseyside and North Wales Division). The turbines of these sets are to be designed to operate under steam conditions of 1500 psig at a temperature of 1000°F, with reheat to 1000°F. The alternators will be hydrogen-cooled. These turbo-alternator sets will be made in the new BTH Turbine Factory at Larne, Northern Ireland, and are to be ready for commercial load during 1961 and 1962.

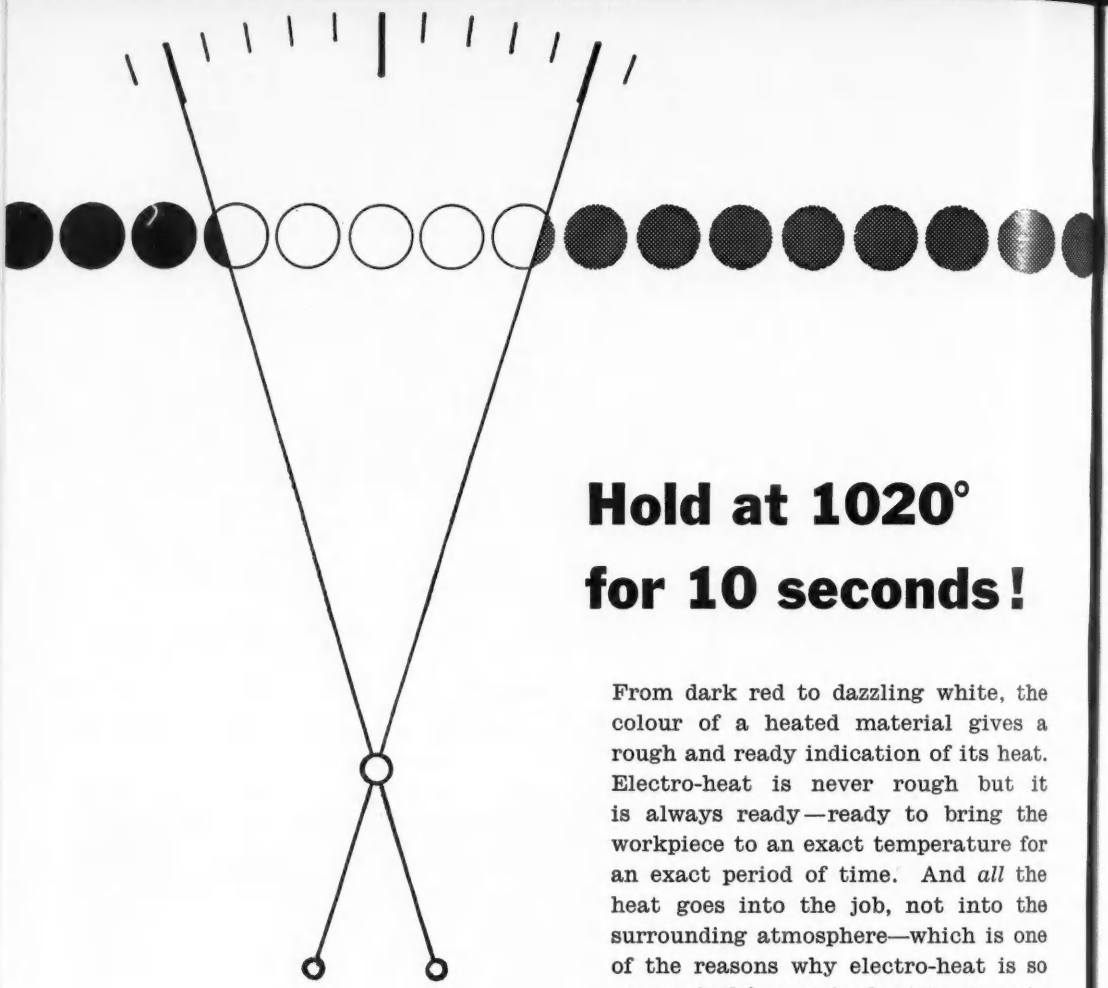
One of the largest lift contracts in India has been secured by **Marryat & Scott Ltd.** for 28 heavy-duty goods lifts at Calcutta Docks. The contract, which includes installation on site, was the result of a joint tender submitted by Marryat & Scott Ltd. and **F. & C. Osler (India) Ltd.**, against international competition. F. & C. Osler, one of the group of companies controlled by Mr. Haridas Mundhra, has represented Marryat & Scott for 27 years, and plans for closer co-operation between the two companies have already reached an advanced stage. The 28 lifts, for Kidderpore and King George V Docks, Calcutta, are to be delivered over a period of 18 months, and will be capable of handling 1000 tons of freight per hour. The consulting engineers to the Commissioners of the Port of Calcutta are **Messrs. Rendel, Palmer & Tritton** of London.

An important contract received by **Standard Telephones and Cables Limited** through their associates, **The Nippon Electric Co. Ltd.**, Tokio, for the provision of an extensive super-high-frequency radio network in Japan, has recently been successfully completed. The network caters for multi-channel telephony simultaneously with television, between Osaka and Fukuoka.

For accuracy, ease of reading, robustness, economy and long, trouble free life install Rototherm Thermometers, Controllers and Recorders. Specialists in bi-metallic applications. *Write for details.*

Rototherm

BI-METAL MERCURY-IN-STEEL VAPOUR PRESSURE
THE BRITISH ROTOTHERM CO. LTD.
Merton Abbey, London, S.W.19 **LIBerty 7661**
Midland Factory: Hollis Street, New Basford **Nottingham 77847**



Hold at 1020° for 10 seconds!

From dark red to dazzling white, the colour of a heated material gives a rough and ready indication of its heat. Electro-heat is never rough but it is always ready—ready to bring the workpiece to an exact temperature for an exact period of time. And *all* the heat goes into the job, not into the surrounding atmosphere—which is one of the reasons why electro-heat is so economical for precise heat treatment.

In every industry, for scores of applications, electricity means higher productivity.

Electricity for Productivity

'Induction and Dielectric heating', just published, is a very important addition to the E.D.A. series of books on Electricity and Productivity. Other titles available are Electric Motors and Controls, Higher Production, Lighting in Industry, Materials Handling, and Resistance Heating. Price 8/6, or 9/- post free.

If you would like further advice or information on how electricity can improve productivity, get in touch with your ELECTRICITY BOARD, or with E.D.A. They can lend you, without charge, films about the uses of electricity in industry.

Issued by the
British Electrical Development Association
2 Savoy Hill, London, W.C.2

Metropolitan-Vickers—GRS Ltd. has been awarded a contract worth over £1,000,000 from the **Rhodesia Railway Board** for the supply and installation of " cTc " (centralized traffic control) equipment between Kalomo and Ndola, a distance of 439 miles. This covers both cTc supervisory equipment and signalling and interlocking equipment, including searchlight-type signals, and is one of the largest orders ever placed for railway signalling equipment of this kind. The new order represents an extension of the 122-mile section from Thomson Junction to Zimba.

An order from the **U.S.S.R.** for four of their sliding-shoe pumps has been received by **Megator Pumps & Compressors Ltd.**, 43 Berkeley Square, London, W.1. The order comprises two Megator R12 pumps, which have a capacity of 3·35 tons per hour and suction lift of up to 24 feet, and two Megator DK5 double-rotor pumps, fitted with eight shoes which have a capacity of 66 tons per hour and a suction lift of approximately 20 feet. It is understood that the pumps will be used for marine purposes.

The **English Electric Company Limited** has received a further order from the **Spanish National Railways** (R.E.N.F.E.) for fifteen 3600-hp, 3000-V d.c. electric locomotives. These locomotives will be identical to the sixty English Electric locomotives now in successful operation in the North of Spain. The Vulcan Foundry Limited, of Newton-le-Willows, Lancashire, which built the mechanical parts of the previous sixty locomotives, will also make those for the latest order. The English Electric Company has also received a further order for electrical equipment for the **Aviles Steel Works**, also in the North of Spain. The company has already executed orders amounting in all to about £1,500,000 for mill drives and distribution and rectifier equipment for the Aviles Steel Works. The value of the new locomotive and steel-mill electrical-equipment orders is approximately £1,800,000.

Among orders placed recently with **British Oxygen Gases Limited** is one for 51 sets of the new Saffire oxy-acetylene hand-welding and cutting blowpipes, together with spares and servicing tools, which will be used for work on the **Kuwait Oil Refinery** extension. Work on the extension is being carried out under the American supervision of **Betchtel Wimpey Limited**, an associate company of **George Wimpey and Company Limited.** The order is worth about £2300. A further order, valued at 83,000 dollars has been secured from the **U.S. Navy**, for equipment to be used in N.A.T.O. dockyards in Spain. Included in the order are two Bison oxy-acetylene cutting machines, each 84 in. wide and 378 in. long, with accessories ; and 10 Bantam cutting machines, with 12-ft lengths of track. Another order has been placed from Sweden for 100 Saffire 18 in./90° cutters, 25 heavy duty cutters (27 in./75°), and accessories. The value of this order is £1700, and the equipment has been ordered by **Aga Svenska A.B. Gasaccumulator Lidingo,** of Stockholm.

The contracts recently announced by the Southern Region of **British Railways** in connection with electrification extensions to the East Kent Coast include orders placed with **The General Electric Co. Ltd.,** London, totalling over £1½m. for converting plant, switchgear, and remote supervisory control. These cover mercury-arc rectifier equipment and metal-clad switchgear for a total of 32 substations, together with the associated substation cabling and d.c. busbars.

Metropolitan-Vickers Electrical Co. Ltd., Manchester, has received an order for two 150-MW turbine-generator sets, complete with condensing, feed-water heating, and de-aerating plant, from the **Montreal Engineering Co. Ltd.** These machines are believed to be the largest ever purchased by any privately owned utility outside the U.S.A. The equipment covered by the contract, which is worth more than 5,500,000 dollars, will be manufactured at the company's works at Trafford Park, Manchester, and Germiston, Glasgow. It will be installed at the Wabamun power station of **Calgary Power Ltd.,** where the first of two Metropolitan-Vickers sets of 66-MW capacity was recently commissioned.

Another order representing valuable dollar business for Great Britain has just been received by **Metropolitan-Vickers Electrical Export Co. Ltd.** It covers two main turbine-generator sets, each rated at 66 MW for installation in Arriaga No. 2 power station at Maracaibo, Venezuela. They will be supplied complete with all condensing, feed-water heating, and de-aerating and evaporating plant. The contract, the value of which approaches 3,000,000 dollars, was placed by **Montreal Engineering Co. Ltd.** on behalf of their associates International Power Co. Ltd., of which C.A. Energia Eléctrica de Venezuela is a subsidiary. The whole of the plant will be manufactured at the Metropolitan-Vickers factories at Trafford Park and Germiston (Glasgow).

The Government of Fiji has awarded a contract for the provision of ship-repairing accommodation at Suva to **Head Wrightson Teesdale Ltd.,** a subsidiary of Head Wrightson & Co. Ltd. This development project includes the supply of slipway cradles and haulage gear capable of handling passenger and cargo ships of up to approximately 1000 tons. The Consulting Engineers for this project are **Messrs. Wilton and Bell.**

Orders for two new super-tankers, each of 47,400 tons, have now been placed with **Vickers Armstrongs Limited** by **Esso Petroleum Company Limited**. They will be completed in 1962 and 1963. A third vessel of similar size is to be built by **Kockums** at Malmo, Sweden, for delivery in 1961. Options are held to increase the size of these vessels, as well as some of the fifteen ships previously ordered, to 65,000 tons.

Pye Limited are designing and supplying all the equipment for a laboratory for the **Atomic Energy Authority** at Dounreay, in which irradiated fuel elements from the Dounreay fast breeder reactor are to be examined. The equipment to be supplied includes manipulators, universal cutting machines, lathe, furnaces, X-ray and density measurement, inspection and material testing machines, optical and TV viewing facilities, and all the associated handling and shielding equipment ; in fact, the complete laboratory, except for the concrete structure, is being supplied by Pye Limited. Owing to the highly radioactive nature of the elements, which can only be handled by remote control, the laboratory is a cave of U-shaped form—a concrete cave with an area of 1100 square feet. To form a biological shield, the walls of the cave are 4 ft 6 in. thick, partly lined with steel.

Metropolitan-Vickers Electrical Co. Ltd. has been entrusted with the supply of mass spectrometry equipment and vacuum furnace equipment to the **United Kingdom Atomic Energy Authority** for installation in connection with the Experimental Fast Reactor at Dounreay.

The National Gas & Oil Engine Co. Ltd., of Ashton-under-Lyne, has received two recent orders from Pakistan and Iran. The first is for two National B2AUP6 type, six-cylinder, pressure-charged, dual-feed engines each developing 1460 bhp at 333 rpm, and each driving a Brush 1000-kW, 3·3-kV, 3-phase, 50-cycle alternator. These are the first National pressure-charged dual-fuel engines to be installed in Pakistan and will be the largest National engines of any type in that country. They are for the Moghalpura power station of the North Western railway and will replace two existing engines. They are

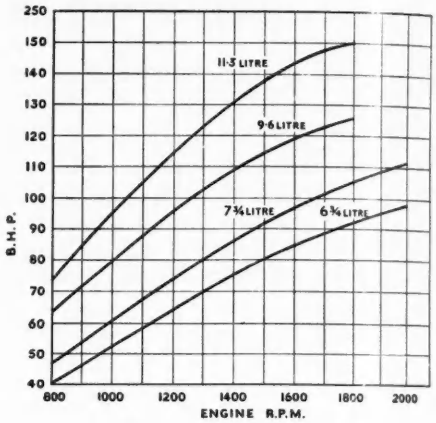
A.E.C. DIESEL ENGINES

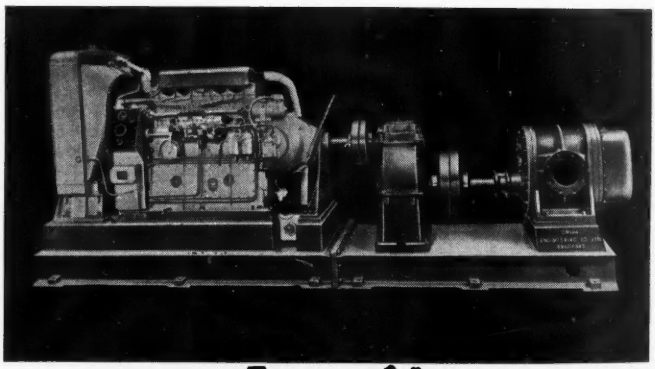
The answer to your power problem

For maximum *usable* power at the most economical r.p.m. in 50-150 b.h.p. diesels, the self-contained, soundly-designed A.E.C. industrial engines are the right answer to your power problems.

Before powering or re-powering mobile or stationary plant or equipment, investigate the technical features of this well-tried and always dependable range of direct-injection diesel engines.

In every application they mean a higher standard of efficiency.





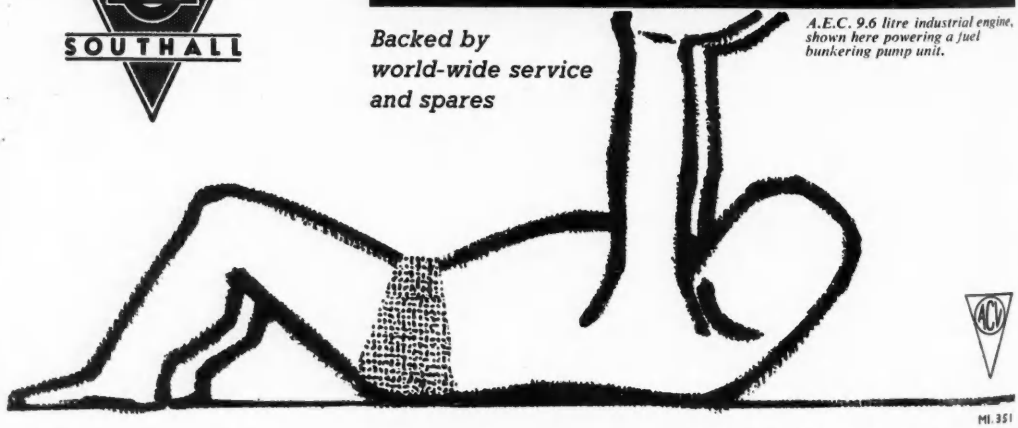
A.E.C. 9.6 litre industrial engine, shown here powering a fuel bunkering pump unit.

A.C.V. SALES LTD.,
Marine and Industrial Division
A.E.C. WORKS, SOUTHALL, MIDDLESEX

THE A.C.V. GROUP OF COMPANIES INCLUDES A.E.C., CROSSLEY MOTORS and THE MAUDSLAY MOTOR CO.

AEC SOUTHALL

Backed by world-wide service and spares



MI.351

due for delivery from the works in November 1957. The second order is for two B4AU8 type, eight-cylinder, pressure-charged engines with a continuous site rating of 1870 bhp at 333 rpm and a one-hour rating (site) of 2051 bhp at 333 rpm (ambient temperature 104°F at an altitude of 4000 ft). Each engine is coupled to a Brush 1310-kW, 6·6-kV, 3-phase, 50-cycle alternator. These units are due for delivery from the works in September 1957 and will be delivered to Sherkate Sahami Electriki Fierouz of Teheran.

Rhodes, Brydon & Youatt Limited, Stockport, have received an order from **Boving & Co. Limited,** London, for the supply of seven vertical motor-driven drainage pumps for installation in the power station in Kariba Gorge.

Pirelli-General Cable Works Limited has been awarded a contract worth approximately £100,000 for the manufacture and installation of circuits totalling some 5721 yards of 0·4-sq in. single-core copper conductor 275 kV oil-filled cable at Drakelow Power Station. The cables will run between the outdoor-type sealing ends at transformers and outdoor sealing ends in the switching station. A Pirelli-General 275-kV oil-filled cable has been in operation for over two years at the Central Electricity Authority's testing station at Staythorpe. This cable, together with joints and terminations, has passed the C.E.A. acceptance tests with an ample margin.

Classified Advertisements

The rate for all classified advertisements is 6d. per word ; in bold print 9d. per word ; minimum order 6s. Box-number advertisements 1s. extra. Instructions, together with remittance, must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

WORK WANTED

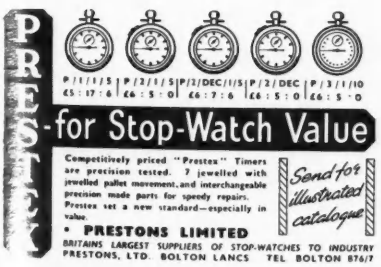
Cut Wires, Pins, Special Rivets, Formed Wires, Manufactured to Specification by Wire Products and Machine Design Ltd., No. 4, Bridge Road, Haywards Heath, Sussex, Phone 1990.

MACHINERY FOR SALE

12 ft × ¼ in. BENNIE FOLDING MACHINE for sale. Motor driven Swing Beam Universal Folding, Rounding and Box Forming Type. Max lift of top beam 18½ in. Adjustment to bed and folding beam 8 in. Smallest trunk formed over beam 18 in. × 18 in. Largest tube formed 16 in. diameter. Gearbox drive with lever control to reversing friction clutches, operating all beams. Safety slipping clutch between gearbox and main drive shaft. Weight about 14 tons. Full details, illustrations, etc., from F. J. Edwards Limited, 359 Euston Road, London, Euston 4681, or 41 Water Street, Birmingham 3, Central 7606.

WANTED

Copies of the February 1957 issue of THE ENGINEERS' DIGEST are urgently required. 4/6d. each will be paid for copies in good condition returned to The Subscription Department, THE ENGINEERS' DIGEST, 120 Wigmore Street, London, W.1.


PRESTON
P/1/1/5 £5 : 17 : 6
P/2/1/5 £6 : 5 : 0
P/3/DEC/1/5 £6 : 7 : 6
P/2/DEC £6 : 5 : 0
P/3/1/10 £6 : 5 : 0
for Stop-Watch Value
Competitively priced "Prestex" Timers are precision tested. 7 jewelled with jewelled pallet movement, and interchangeable precision made parts for speedy repairs. Prestex set a new standard—especially in value.
Send for illustrated catalogue
• PRESTONS LIMITED
BRITAINS LARGEST SUPPLIERS OF STOP-WATCHES TO INDUSTRY
PRESTONS, LTD. BOLTON LANCS TEL BOLTON 876/7

NEW BALL & ROLLER BEARINGS

OVER 4,000,000 IN STOCK
IN MORE THAN 4,000 TYPES

BRITAIN'S LARGEST STOCKS

STOCK LIST AVAILABLE

CLAUDE RYE BEARINGS

895–921 FULHAM ROAD, LONDON, S.W.6
Renown 6174 (Ext. 24) Cables: Rybearings, London Telex 23453

CUT MACHINING COSTS

ALLOY STEEL CASTINGS

OVER 40 SPECIFICATIONS
PROTOTYPES A SPECIALITY

Small or large quantities with a maximum individual weight of approximately 20 lb. Radiographic examination available. Our technical staff will be pleased to advise you on design and material problems.

PRECISION ALLOY CASTINGS (BIRMINGHAM) LIMITED

MACKADOWN LANE, KITTS GREEN, BIRMINGHAM, 33
Tel. STECHFORD 3071

The Specialist Foundry
for
BLACKHEART MALLEABLE IRON CASTINGS
•
HEAT & ABRASION RESISTING ALLOY CASTINGS
•
Manufacturers of
"PULMAC" PULVERISING MILLS

Follsain-Wycliffe Foundries Limited
LUTTERWORTH, NR. RUGBY Tel. 10, 60 & 152

Do you know the name for Plastics Mouldings?

Those with a leaning to Lexicon would no doubt essay DRIED LAG or even DEAD GIRL, but the alert buyer of plastics mouldings who puts down ALDRIDGE *would have a winning hand in more than one sense!*

ALDRIDGE is a comparatively new name in the moulded plastics field. It is a vigorous Company enjoying the benefits of the most modern factory and plant, and administered and staffed by men whose knowledge and experience of plastics mouldings extends back to the beginning of the Industry itself. ALDRIDGE make all types of thermo-setting and thermo-plastic mouldings for the leading names in many Industries . . . . . ALDRIDGE is ready to serve YOU!

ALDRIDGE for PLASTICS mouldings

ALDRIDGE PLASTICS LTD.

An A.E.I. Company

REDHOUSE INDUSTRIAL ESTATE, ALDRIDGE, STAFFS.
TELEPHONE: ALDRIDGE 52031 (4 LINES)

A.I.D. APPROVED. CONTRACTORS TO H.M. GOVERNMENT DEPARTMENTS

L.G.B.

BOOKS RECEIVED

Principles of Engineering Inspection. By Geoffrey K. King, A.M.I.C.E., A.M.I. Mech.E., A.M.I.E.I., and C. T. Butler, B.Sc.(Eng.) A.M.I.Mech.E., M.I.Prod.E. 272 pp., 132 illustrations. Publishers : Cleaver-Hume Press Ltd., 31 Wright's Lane, Kensington, London, W.8. Price : 25/–.

Covering organization, methods, machines, and sampling, and including the use of quality-control charts, this well-written book is a detailed, up-to-date, and authoritative work on a very important aspect of mass production. The emphasis throughout is on principles, and it deals not only with finished components but also with metallic and non-metallic materials and even protective coatings.

Fundamentals are simply but adequately explained, and a wealth of excellent illustrations is included. In this connection, while many modern machines are depicted, line diagrams are often included to show their construction and method of operation. There can be no doubt that this is a useful book, of special interest to students and to managers and inspectors in industry.

Diesel Fault Tracing, Maintenance, and Repair. 2nd Edition, 1957. By Staton Abbey. 254 pp., 118 illustrations. Publishers : Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price : 16/–.

Since the first edition of this popular book was published in 1950, the use of high-speed diesel engines has continued to increase, and several new types have been introduced. This new and revised edition will therefore be of undoubted value both to the experienced mechanic and to those owners who may have to undertake maintenance and fault tracing with limited equipment.

The book covers concisely but authoritatively all types of high-speed diesel engines, including transport, tractor, marine, stationary, etc. To assist in rapid and accurate fault tracing, ten systematic diagnosis charts have been included, together with a considerable amount of supplementary material.

Project Engineering of Process Plants. By Howard F. Rase and M. H. Barrow. 692 pp., 164 illustrations. Publishers : John Wiley & Sons, Inc., New York, and Chapman & Hall, Ltd., 37 Essex Street, London, W.C.2. Price : 114/–.

Not only is this the first book to formalize the methods of executing a project used by all progressive chemical companies and engineering firms, but it is also the first work to be devoted to process-plant design, in accordance with modern techniques of project organization, planning, and execution.

The authors, both experienced in the field of project engineering, approach the subject from the point of view of the specialist who has organizational and technical ability in all phases of engineering, and who is able to co-ordinate and supervise the design and construction of a modern plant. However, the book is not limited solely to the project engineer, as it is of undeniable value to any engineer whose work requires a knowledge of the theories and techniques of mechanical design, procurement, and construction.

To facilitate understanding, the book includes many illustrations of equipment and examples of actual design calculations, specifications, and contracts. In addition, references to information recorded in handbooks and codes, together with all other sources of practical information, are included.

LATEST INDUSTRIAL LITERATURE

1. Gauges. Specifications and dimensional drawings of an extensive range of gauges are given in a neatly-produced illustrated 36-page booklet. Details are included of compound gauges, hydraulic gauges, combined altitude gauges and thermometers, etc. Useful information is also given on size and on working and fluctuating pressures, corrosive media, and temperature, together with pressure and conversion tables. In addition, a section on accessories and special features is incorporated.

All gauges are recorded, thus enabling any fault in material or workmanship to be traced, and their accuracy is guaranteed within the limits recommended by the relevant British Standard Specification. A selection of special-purpose instruments is also listed.

2. Bench-Type Spot Welders. Details of two new models of bench-type spot welder, with respective capacities of 4 and 8 kVA, are given in an illustrated leaflet. Amongst other interesting features are aluminium side castings which enclose the machine and reinforce the frame to give complete rigidity, an indexed dial providing variable welding times, and a plastic connecting tube between two hollow electrode holders showing visual indication of water flow. Pressure control is located on top of the machine, ensuring easy regulation.

The machine incorporates an air-cooled single-phase transformer, the primary windings of which are connected to a 4-point tapping switch for heat regulation. Useful items of ancillary equipment include a water-cooled bottom arm with electrode tip for welding in limited spaces, a water-cooling system with circulating pump, and a range of electrode tips suitable for various applications.

3. Aluminium-Bronze Diecastings. Useful information on the properties and design of aluminium-bronze diecastings is contained in a 24-page illustrated booklet. A number of typical applications is shown, together with details of wear resistance and corrosion resistance.

A further section is incorporated on the finishing of aluminium-bronze diecastings, including notes on cleaning processes, painting and enamelling, solution bronzing, electroplating, soldering, and welding. Reference is also made to machining aluminium-bronze diecastings.

4. Annular Piston Pumps. General applications and principles of operation of annular piston pumps, together with viscosity-comparison charts and pressure and volume conversion tables, are contained in a well-produced loose-leaf folder. Excellent detailed drawings are also included.

The annular piston pump described is a small-capacity rotary oil pump with a volumetric efficiency as high as 99% under good working conditions. Pressures up to 1500 psi can be obtained with running speeds from 20 to 1500 rpm. Noteworthy features include positive action and steady uniform flow at slow speeds ; no aeration or turbulence ; no idle pockets or passages to cause air-locks or coagulation ; and no springs, valves, or gears, etc.

5. 400-Cycle Power Supplies. A range of alternators designed to meet the growing need for 400-cps and other high-frequency supplies is presented in an illustrated 4-page leaflet, the basic standard frequency in the selection shown being 400 cps. The generator, which can be driven by any prime mover, is designed to ensure inherently low harmonic and negligible sub-harmonic content of the output waveform. Voltage controls follow conventional lines. For normal applications, electro-mechanical voltage regulators are used, whereas, for highest performance, both with regard to accuracy and reliability, magnetic-amplifier automatic voltage regulators are available.

6. Sliding-Bed Lathes. Details and specifications of sliding-bed lathes are contained in a 14-page illustrated brochure The lathes described combine the usefulness of a standard straight-bed lathe with some of the advantages of a break-lathe. When the bed is closed, the machine is, to all intents and purposes, a standard centre-lathe. If, however, it is required for a large-diameter job of some length, the bed may be opened, so that considerable capacity may be admitted in the adjustable gap. Furthermore, special attachments are available to enable the whole of the outside diameter of a job to be machined, thus extending still more the value of the machine.

7. Cross-Roll Bearings. Stated to be the first really perfect slewing-ring, the new cross-roll bearings described in a 4-page illustrated leaflet are claimed to change the slewing-ring—up to now the weakest spot of any machine—into the strongest part of an excavator by achieving 100% perfect distribution of the load, thus reducing maintenance to the absolute minimum.

Within a given diameter, the load-carrying capacity of an excavator fitted with this bearing is greater than it would be with any other type of slewing gear ; in addition, the whole unit is grease-packed for life, and, as there is never any need for alignment or adjustment, maintenance is unnecessary between major overhaul periods.

8. Protective Devices for Electrical Switchgear. Descriptive details of protective devices applied to electrical switchgear are given in a 34-page illustrated brochure. Although it deals only with the more general forms of protective equipment, in a range up to 11 kV and 250 MVA breaking capacity, practically all other requirements can be covered quite easily by simple arrangements of either direct-acting trip coils or relays.

General recommendations for the protection of such items of equipment as transformers, motors, and feeders are given, together with several useful diagrams. In addition to notes on thermal relays, current grading, earth fault protection, etc , a special section is devoted to application guidance.

9. Engineers' Pneumatic Tools. Representative examples of a wide range of engineers' steel tools are described and illustrated in three well-produced leaflets. Details of an improved high-speed twist drill are given, which, at no extra cost, retains the advantages of steam temper, i.e., toughness, freedom from stress, corrosion resistance, etc. A selection of varying types of pneumatic chisels is also presented, these being made of silicon and chromium steel ; silicon, molybdenum, and vanadium steel ; and silicon, chromium, tungsten, and vanadium shock- and fatigue-resisting tool steel.

Also included are details of rivet snaps, designed to give greater strength at the neck of the shank. These are supplied with a loose washer to absorb the rebound of the hammer, and may be re-cupped a greater number of times than the ordinary pneumatic snaps.

In addition, descriptions are given of four drill sets packed in metal containers about the size of a cigarette case. Opening the cover erects the drills, and a useful bench stand is formed, giving instant selection by clearly marked sizes on the case.

MAIL THIS COUPON TO-DAY

THE ENGINEERS' DIGEST, 9.57
120 Wigmore Street, London, W.1.

Date.....

Please send free and without obligation the literature indicated by the following circled numbers :

1 2 3 4 5 6 7 8 9

Name .....

Position .....

Company.....

Address .....

PNEUTOMATION

Registered Trade Mark

at work This Auto Boring machine at Messrs. S. & H. McLaren Ltd. of Leeds is another example of how Pneutomation is increasing output and cutting costs.

LANG PNEUMATIC CONTROL GEAR

entirely non-corrodible

Plan with

LANG PNEUMATIC LTD

VICTORY WORKS BIRMINGHAM ROAD WOLVERHAMPTON Tel 25221 2 3

P.130